THE KANSAS UNIVERSITY SCIENCE BULLETIN.

Vol. V, No. 11 — April, 1910.
(Whole Series, Vol. XV, No. 11.)

CONTENTS:

HISTOLOGY OF TOWNSENDIA EXSCAPA AND LESQUERELLA SPATHULATA,
Lilian Bunton.

PUBLISHED BY THE UNIVERSITY
LAWRENCE, KAN.

Entered at the post-office in Lawrence as second-class matter.

THE KANSAS UNIVERSITY SCIENCE BULLETIN.

VOL. V, No. 11] APRIL, 1910. [WHOLE SERIES VOL. XV, No. 11

HISTOLOGY OF TOWNSENDIA EXSCAPA AND LESQUERELLA SPATHULATA.

BY LILIAN BUNTON.

Plates XXXVIII to XLV.

TWO excellent representatives of xerophytic vegetation, *Townsendia exscapa* and *Lesquerella spathulata*, were collected in Gove county, Kansas, at an elevation of 2700 feet. These plants are not common throughout this district and are limited to certain localities. *Townsendia* was found growing in draws in the immediate vicinity of the town of Gove and also on the flat, open prairie around "Castle Rock," about twenty-five miles southeast of Gove, and in the vicinity of a group of rocks known as the "Pyramids," thirty miles southwest.

A general idea of the appearance of the vegetation of this district may be derived from figure 1. My examples of *Townsendia*, therefore, were growing on the flat, open prairie as well as in the draws, occurring not in clumps or patches, but as isolated individuals within three or four feet of one another. The plants on the open prairie show a more luxuriant growth than those in the draws.

The specimens of *Lesquerella* were collected about twelve miles southwest of the town of Gove on a rocky, clay bluff. This plant, unlike *Townsendia*, was found growing not as isolated individuals but in rather large colonies.

Of all the ecological factors influencing the structure, habit and distribution of plants the most potent is the water supply. In Gove county the total precipitation for the year 1904 was 18.10 inches; the greatest monthly precipitation was 4.13 inches, in May; the least monthly precipitation was 0 inches in February and November. The total snowfall for the year was 5.5

inches and the number of rainy days 39. In the following table is given the monthly and annual precipitation in Gove county for the year 1904, with departures from the normal:

January.		July.	
Precipitation	0.01	Precipitation	2.18
Departure	—0.57	Departure	—1.47
February.		August.	
Precipitation	0.00	Precipitation	2.57
Departure	—0.72	Departure	+1.11
March.		September.	
Precipitation	1.00	Precipitation	1.26
Departure	+0.32	Departure	—1.08
April.		October.	
Precipitation	1.79	Precipitation	2.00
Departure	—0.27	Departure	+0.98
May.		November.	
Precipitation	4.13	Precipitation	0.00
Departure	+0.89	Departure	—0.51
June.		December.	
Precipitation	2.62	Precipitation	0.55
Departure	—1.25	Departure	+0.03

Annual.
Precipitation 18.10
Departure ..... —2.27

From comparisons with other places in Kansas where weather records have been kept, it is seen that the amount of precipitation of this habitat is remarkably small; in fact, being the least, excepting that of Oberlin, Lakin, and Dodge City, where the annual precipitation was 15.72 inches.

One may acquire a general idea of the temperature of this locality from the following tables:

Monthly and annual mean temperature for year 1904, with departure from normal, Fahrenheit.

January.		July.	
Temperature	29.0	Temperature	74.8
Departure	+0.9	Departure	—3.8
February.		August.	
Temperature	30.6	Temperature	72.6
Departure	+1.9	Departure	—4.0
March.		September.	
Temperature	43.8	Temperature	68.3
Departure	+6.4	Departure	—0.1
April.		October.	
Temperature	48.6	Temperature	55.3
Departure	0.0	Departure	+1.5
May.		November.	
Temperature	57.8	Temperature	44.6
Departure	—4.6	Departure	—0.9
June.		December.	
Temperature	67.4	Temperature	30.2
Departure	—4.9	Departure	—2.4

Annual.
Temperature 51.9
Departure ..... —0.5

Monthly maximum temperatures for the year 1904, with dates.

January 18	65°	July 29	102°
February 9	72°	August 24	95°
March 2	82°	September 9	103°
April 10	79°	October 3	87°
May 24	93°	November 18	73°
June 23	99°	December 31	68°

Monthly minimum temperatures for year 1904, with dates.

January 25	—2°	July 26	54°
February 19	3°	August 22	50°
March 3	6°	September 14	41°
April 17	25°	October 25	25°
May 14	34°	November 11	11°
June 11	50°	December 26	4°

Another ecological factor which has much to do in shaping plants is the wind. On the prairies the wind has full sweep; it blows most of the time at a rapid rate and tends to dry up whatever vegetation there may be in its path. No definite statement can be made as to the velocity of the wind of this special locality. In the following table, however, are shown some of the results of observations made by Stevenson, of Edinburgh, upon the increase in velocity of the wind with the height above the ground, as given in Schimper's Plant Geography:

Height of instrument aboveground, in feet.	Velocity of wind in miles per hour.
½	6.83
2⅓	8.73
4⅓	9.77
9½	10.45
14	10.54
25	11.54
50	12.21

Height of instrument aboveground, in feet.	Velocity of wind in miles per hour.
½	9.8
3½	12.4
9	13.8
14	14.3
25	15.0
51	16.3

Height of instrument aboveground, in feet.	Velocity of wind in miles per hour.
1⅓	22.2
3½	25.6
9	31.9
14	33.7
25	37.1
51	42.7

From the above tabular statement it is quite clear that plants that are only slightly raised aboveground experience the effects of the wind much less than tall plants, and especially trees.

The action of the wind on plants is partly direct by tensile stresses and partly indirect by increasing transpiration; both these actions are the more energetic the taller the plants or the higher their location.

Where my *Townsendias* occurred the soil is a loose, calcareous deposit, allowing the water quickly to percolate through it.

When the character of its habitat is considered, it would be expected that the anatomy of *Townsendia* must be that of a xerophyte.

TOWNSENDIA EXSCAPA.

Townsendia exscapa is perennial from a woody taproot which averages ten centimeters long and three to four millimeters in diameter at the thickest portion. The stem grows from one to four inches high. The fact that this plant is low helps it to endure the strong winds prevailing in its locality.

The character of the stem varies in different plants. In some, while young, it is quite simple, bearing only a few heads of flowers; in others it is several-branched, bearing six or more heads. As a rule, however, it gradually becomes more and more branched with age until the whole plant may attain a breadth of ten to twelve inches, bearing about 100 heads of flowers. The leaves are all clustered at the base, narrowly linear or slightly spatulate, and one to two inches long. The flowers are white and are borne in sessile heads one to one and one-half inches broad. In figure 2 is shown a photograph of *Townsendia*. When the flowers of the larger plants have gone to seed the plants have the appearance seen in figure 3.

In the discussion of the histology of *Townsendia* the stem will be first treated, then the root, and last the leaf, and the different tissue systems under each will be examined.

The Stem.

Tegumentary Tissues.—The protection of the mature stem is provided for by a cutinized epidermis and cork tissue. All the walls of the epidermis are cutinized. In figure 4 is shown a small portion of the cutinized epidermis. In the following table is given the average thickness of the walls of the epidermal cells and the average length and width of the cavity of

the epidermal cells of *Townsendia* and a few mesophytes and xerophytes:

		Outer wall.	Inner wall.	Radial wall.	Vertical length.	Radial width.
MESOPHYTES.	Eupatorium altissimum.	0.005 mm.	0.001 mm.	0.001 mm.	0.023 mm.	0.015 mm.
	Salvia azurea.	0.006 mm. Cutinized portion, 0.005 mm. Cuticle, 0.001 mm.	0.006 mm.	0.003 mm.	0.02 mm.	0.01 mm.
HYDROPHTES.	Sagittaria.	0.003 mm.	0.001 mm.	0.001 mm.	0.02 mm.	0.01 mm.
	Nelumbo-lutia.	0.006 mm.	0.003 mm	0.003 mm.	0.04 mm.	0.02 mm.
TOWNSENDIA.	.....	0.05 mm.	0.02 mm.	0.018 mm.	0.09 mm.	0.068 mm.

In the following table is given the average thickness of the layer of cork, the average thickness of the walls of the cork cells, and the average length and width of the cell cavity in *Townsendia:*

Thickness of cork.....	4-7 cells.
Average thickness of wall.....	0.004 mm.
Average length of cavity.....	0.14 mm.
Average width of cavity.....	0.087 mm.

In figure 5 is shown a small portion of cork tissue in cross section.

When compared with the mesophytes and hydrophytes above mentioned, it is seen that *Townsendia* has a well developed protective system, one of the primary requisites of a plant growing in a dry, windy habitat.

The Strengthening Tissues.—The strengthening tissues found in *Townsendia* consist exclusively of collenchyma and short sclerenchyma cells. From figures 6 and 7, collenchyma cells as seen in cross and longitudinal sections, it may be seen that the cells of the collenchyma tissue have remarkably thick walls. The walls of the short sclerenchyma cells also are much thickened, as shown in figures 8 and 9. No true bast fibers are found; the tissue that in cross section appeared to be bast when examined longitudinally proved not to be bast, but a tissue of short sclerenchyma cells. Wood fibers are also

wholly lacking. This deficiency, however, is in a measure compensated by the modification of other tissues, the walls of the wood parenchyma, cortex, pith and medullary-ray cells being remarkably thickened. The walls of the cortex and pith cells are, on the average, 0.03 mm. thick. In figures 10 and 11 are shown a few cortex cells as seen in cross and longitudinal sections, respectively. In figures 12 and 13 are shown a few pith cells as seen in cross and longitudinal sections, respectively. As shown in figure 14, the tracheids have thick, lignified walls and constitute the smaller portion of the xylem area; these, together with the wood parenchyma cells, tend to strengthen the plant. A longitudinal section was mounted in a drop of concentrated solution of chromic acid; in a few minutes everything had disappeared but the tracheids. The chromic acid dissolved the wood parenchyma cells, leaving the tracheids isolated as shown in figure 15. The average length of a tracheid is 0.243 mm.; the average width, 0.016. mm.

Tracheal Tissues.—In the stem the conduction of water is provided for by tracheids varying in length, and in longitudinal section having the appearance of typical tracheal tubes. When, however, a longitudinal section was macerated under a cover glass in chromic acid, the tracheids were isolated from the other tissues and stood out prominently as spiral and scalariform tracheids. By computing the number of tracheids in one xylem wedge and multiplying by the number of such wedges, where the cross section of the stem is 19.635 sq. mm. in area, there were found to be 1313 tracheids. The average diameter of these stem tracheids is 0.016 mm. The total water-conducting area of the stem, cross section, is 0.266 sq. mm., which is 1.3 per cent of the whole stem. Of the xylem portion of the stem, 6.6 per cent is given up to tracheids.

When compared with the water-conducting tissue of several mesophytic herbaceous plants, that of *Townsendia* seems quite small. In *Saponaria officinalis* 22.7 per cent of the whole stem is devoted to the conduction of water; of the xylem portion 29 per cent, the average diameter of a tracheal tube being 0.026 mm. Thus it is seen that 17 times as much of the stem of *S. officinalis* as in *Townsendia* is devoted to the conduction of water.

In *Verbena stricta* there was devoted to the conduction of water 9 per cent of the stem cross section, where the area was

found to be 3.801 sq. mm. Of the xylem portion, 62 per cent was devoted to the conduction of water. In *Verbena,* then, there was found devoted to the conduction of water seven times as much of the stem as in *Townsendia.* In *Mentzelia oligosperma* there was devoted to the conduction of water 9 per cent of the stem cross section, where the area was 9.07 sq. mm. Of the xylem portion, 33 per cent was devoted to the conduction of water. In *Mentzelia* also there was found to be devoted to the conduction of water nearly seven times as much of the stem as in *Townsendia.* In *Ambrosia artemisifolia* there was found devoted to the conduction of water 21 per cent of the stem cross section, where the area was 13.86 sq. mm. Of the xylem portion 52 per cent was devoted to the conduction of water. In *Ambrosia,* then, there was devoted to the conduction of water about sixteen times as much of the stem as in *Townsendia.* In *Abutilon avicennæ* there was devoted to the conduction of water 2 per cent of the stem cross section, where the area was 38.48 sq. mm. Of the xylem portion, 6 per cent was devoted to the conduction of water. In *Abutilon,* accordingly, there was devoted to the conduction of water approximately twice as much of the stem as in *Townsendia.*

When compared with the water-conducting tissues of desert plants, which have have been discussed by W. A. Cannon[1] in his paper on the "Water-conducting Systems of Desert Plants," *Townsendia* has a relatively large water-conducting area.

In the following table is given the number of tracheal elements in 1 sq. mm. of stem, cross section, of *Townsendia,* and of several mesophytes and xerophytes; the latter cited from Cannon:

Townsendia	66
Mesophytes:	
Abutilon avicennæ	33
Verbena stricta	734
Mentzelia oligosperma	77
Ambrosia artemisifolia	124
Xerophytes:	
Celtis pallida	1
Covillea tridentia	2
Fouquieria splendens	7

Tissues for Food Conduction and Storage.—The medullary ray is composed of two kinds of cells, some with rather thick

1. Bot. Gazette, June, 1905, pp. 396-408.

cellulose walls which measure 0.001 mm. in thickness. The thick-walled medullary-ray cells constitute approximately one-third of the whole area of a medullary ray. An explanation of there being both thick- and thin-walled medullary-ray cells may possibly be that the thick-walled cells have sacrificed their function of conduction and have assumed that of strengthening. The average vertical length of a medullary-ray cell is 0.01 mm.; the average width 0.008 mm. In figure 16 are shown a few medullary cells as seen in cross section; in figure 17 as seen in longitudinal section.

Very little special provision for the passage of food longitudinally seems to have been made by *Townsendia*. The ordinary collateral vascular bundles are found. A comparatively small portion of the vascular bundle, however, is devoted to phloëm—about 12 per cent; in *Verbena stricta* 25 per cent of the vascular bundle is devoted to phloëm. In *Mentzelia oligosperma* there is the same proportion of the vascular bundle devoted to phloëm as in *Townsendia*—12 per cent. Neither sieve tubes nor sieve parenchyma cells are found in *Townsendia*. The whole work of conduction of food longitudinally is apparently assumed by the cambiform cells and the undivided mother cells of the sieve tubes. Presumably the sieve tubes, when present in a plant, would carry the food more rapidly. The most elaborated sieve tubes are always found in plants of considerable length, especially in trailing, clambering and climbing plants. *Townsendia*, however, is so low that it seems that the food can be conducted longitudinally rapidly enough and in sufficient quantities by the cambiform and undivided mother cells of the sieve tubes without the aid of sieve tubes.

In figure 18 are shown phloëm cells as seen in cross section; in figure 19, as seen in longitudinal section: *a*, cambiform cell; *b*, undivided mother cell of the sieve tubes. The average length of these cells is 0.18 mm; the average width, 0.01 mm. The average thickness of their cell wall is 0.0006 mm.

In *Townsendia*, the xylem parenchyma cells and the medullary ray, cortex and pith cells afford sufficient means for the storage of food. Upon examination of sections of the stem of the plant collected at the time of flowering and fruiting, there appeared stored up in the tissues of the stem no food whatever, thus showing that the food must at this time be used

by *Townsendia* as fast as it is made. No statement, however, can be made of the storage of food in the plant later in the season.

The Root.

Tracheal Tissues.—As in the stem, the conduction of water in the root is provided for by spiral and scalariform tracheids. By computing the number of tracheids in a certain portion of a cross section, and multiplying by the number of such portions, there were found to be 1271 tracheids in the cross section of the root. In figure 20 may be seen how these tracheids are distributed throughout the section. The average diameter of these tracheids is 0.018 mm. The total water-conducting area in a root, where the cross section area is 7.496 sq. mm., is 0.325 sq. mm., or 4.2 per cent of the whole root area.

In structure, the other tissues of the root do not differ essentially from those of the stem; hence the discussion of them as found in the stem will suffice for the root.

The Leaf.

The Tegumentary Tissues.—The outer wall of the epidermis of the leaf is not wholly cutinized; the inner portion is of cellulose and is 0.0108 mm. thick, and the outer portion of the wall is cutinized and is 0.0072 mm. thick. The inner tangential wall is of cellulose and is 0.0036 mm. thick. The radial walls are likewise of cellulose and 0.0036 mm. thick. The average tangential length of the cells of the epidermis is 0.0396 mm.; the average radial length, 0.025 mm. No difference was found between the upper and lower epidermis, hence the figures given above will suffice for both. In figure 24 is shown a portion of the cutinized epidermis as seen in cross section.

Tracheal Tissues.—After a leaf boiled in alcohol had remained in a mixture of chloral hydrate and hydrogen peroxide for several days, it had become so well bleached that its venation could be seen easily with the naked eye. There appeared three prominent longitudinal veins, one central and two lateral, from which extended other veins branching in every direction and terminating in water-storage tracheids, as shown in figure 21*a*. In the cross section of the midrib through the center of the leaf were found ninety-five tracheids, the average diameter of which was 0.0075 mm., making the

total water-conducting area there 0.00004 sq. mm. The cross-section area of the midrib was 0.01207 sq. mm., 32 per cent of which was devoted to conduction of water. In figure 21*b* is shown the midrib as seen in cross section. In the cross section of each of the lateral veins were found twenty-eight tracheids, the average diameter of which was 0.0059 mm., making the total water-conducting area in each vein 0.00073 sq. mm. The total cross-section area of each vein was 0.003 sq. mm., 24 per cent of which was devoted to the conduction of water. The average distance between the ultimate branches of the veins—*a* and *b*, figure 22—is 0.031 mm.

In the leaf, the phloëm consists only of cambiform cells and undivided mother cells of the sieve tubes; the xylem is made up of wood parenchyma cells and spiral and scalariform tracheids. The average diameter of the cavity of the tracheids is 0.006 mm. The walls of the parenchyma cells, however, remain quite thin. In figure 23 are shown the phloëm cells as seen in longitudinal section of the midrib: *a*, cambiform cell; *b*, undivided mother cell of the sieve tubes. The average length of these cells is 0.14 mm., the average width 0.01 mm., the average thickness of the cell wall 0.0006 mm.

The Photosynthetic Tissues.—On both sides of the leaf are found palisade cells; the spongy parenchyma cells are not very prominent and towards the center of the leaf, in some places in the leaf not really being differentiated from the palisade cells. The explanation of the palisade cells on both sides of *Townsendia* may be that out on the open prairie the reflected light from below is sufficiently intense to stimulate the formation of palisade tissue on the under side of the leaf.

On each side of the leaf there are from two to three layers of palisade cells, the average length of which is 0.14 mm., the average width 0.05 mm. The average number of chloroplasts in a single cell is twenty-nine and the average diameter of a chloroplast is 0.0008 mm. In figure 25 are shown the palisade cells as they appear in surface view; in figure 26 spongy parenchyma cells as they appear in surface view.

In the following table is shown the number of chloroplasts

found in a single mesophyll cell of a number of plants, as given in Haberlant's "Pflanzen-Anatomie":

	Palisade cells.	Spongy parench. cells.
Fragaria elatior	86	14
Pulmonaria officinalis	85	15
Ricinus communis	82	18
Brassica rapa	80	20
Galeopsis tetrahit	79	21
Fropaeolum majus	77	23
Helianthus annuus	73	27
Phaseolus multiflorus	69	31
Bellis perennis	67	33

When compared with the plants above mentioned, it is seen that in the leaf of *Townsendia* the chloroplastic surface is relatively small. On both sides of the leaf the number of chloroplasts in a single mesophyll cell is approximately twenty-nine, thus giving to both sides of the leaf the same chlorophyll-producing volume. The small number of chloroplasts found in the mesophyll cells of the upper side allows the sunlight to penetrate to the lower side of the leaf, thus giving to the cells there the power to carry on photosynthesis more effectively.

The Water-storage Tissues.—In the leaf of *Townsendia* there is an admirable arrangement for all the mesophyll cells to have immediate access to water. Throughout the full length of the leaf on both sides are found large cells which are used primarily for the storage of water. These water-storage cells, however, seem to assume other functions; they evidently take part in the conduction of water and aid to a slight degree in photosynthesis. They have very thin walls, which are lined by a few chloroplasts much smaller than those found in the other mesophyll cells. Bordering on these water-storage cells are mesophyll cells which draw upon them for water when there is need.

In order to secure the greatest access to water the palisade cells occur in various relations: bordering on veins, on water-storage cells, on spongy parenchyma cells. In the following table is shown the relative frequency of palisade cells bordering respectively on water-storage cells, veins and spongy parenchyma cells:

Bordering on water-storage cells	222
Bordering on veins	81
Bordering on spongy parenchyma cells	42

From the above figures it is seen that the palisade cells occur most frequently bordering on the water-storage cells, there being nearly three times as many bordering on the water-storage cells as on the veins and twice as many bordering on the veins as on the spongy parenchyma cells. Figure 27 is a diagrammatic drawing, showing the distribution of water-storage cells, *b*, as seen in a cross section of a leaf. In figure 28 are shown the palisade cells, *B*, bordering on water-storage cells, *A*. In figure 29 are shown the palisade cells, *A*, bordering on the veins, *C*. Some places in the leaf the palisade cells, *D*, have still greater access to water, bordering as they do on both water-storage cells, *A*, and storage tracheids, *C*. This relation generally occurs at the ends of the leaf. In figure 30 are shown the palisade cells as found in this relation. Sometimes the palisade cells are found bordering on water-storage cells, *A*, which in turn border on veins, *C*, as shown in figure 31. Such an arrangement as this is an excellent one; for as fast as the water-storage cells are deprived of the supply of water on hand they can immediately draw on the veins and thereby continue to supply the palisade cells with water as it is needed. In figure 32 are shown palisade cells, *A*, bordering on spongy parenchyma cells, *B*.

Another means for storage of water is the water-storage tracheids found at the termination of the veins. Palisade cells bordering on these tracheids can obtain water when there is need. In figure 33 are shown these tracheids as they appear at the ultimate ends of the veins; in figure 34 the water-storage tracheids as they appear in other places in the leaf.

The Aërating Spaces.—In *Townsendia* there were found devoted to aëration only 20 sq. mm. of the surface of a leaf which measured 100 sq. mm.; or, in other words, the volume of the intercellular spaces and the volume of the whole leaf, roughly estimated, stand in the relation to each other as 8:1000. When compared with *Pistia texensis*, an hydrophyte, whose aërating volume and the volume of the whole leaf stand in the relation to each other as 760:1000, the amount of volume devoted to aëration in *Townsendia* seems quite small.

There were found on either side of the leaf an approximate average of 344 stomata to 1 sq. mm., the average number usually found in plants. There was no difference in the char-

acter of the stomata on either side of the leaf. It seems rather surprising to find in the leaf of a xerophyte the usual number of stomata found in plants and to find them at the surface of the leaf instead of being sunken beneath the epidermis; for, as a rule, in xerophytic plants there are fewer stomata and they are often sunken beneath the epidermis.

In figure 35 are shown the stomata as they appear in the surface view of the leaf of *Townsendia*. In figure 36 is shown a stoma as it appears in cross section of the leaf.

SUMMARY.

1. *Size and Habit of Townsendia.*—*Townsendia* is a low plant, growing from one to four inches high; it grows on the flat, open prairie as well as in the draws, and occurs not in clumps but as isolated individuals. The stem is at first relatively simple, but, as a rule, it becomes more and more branched with age until the whole plant may attain a breadth of ten to twelve inches.

2. *Tegumentary Tissues.*—In the mature stem of *Townsendia* the cutinized epidermis, whose outer walls measure 0.05 mm., and the cork tissue several layers thick, constitute the tegumentary tissues.

In the leaf of *Townsendia* there is found an epidermis whose outer wall measures 0.017 mm. in thickness. The outer portion of the wall is cutinized and measures 0.0072 mm. in thickness; the inner portion is of cellulose and measures 0.0108 mm. in thickness.

3. *Strengthening Tissues.*—In *Townsendia* the strengthening tissues of the stem consist of collenchyma and short sclerenchyma cells. True bast fibers and wood fibers are lacking. The remarkably thick cell walls, not only of the strengthening tissues but of nearly all the tissues, make the stem of *Townsendia* strong.

4. *Tracheal Tissues.*—The area devoted to conduction of water in *Townsendia* is comparatively small, there being only 1.3 per cent of the stem devoted to that function. Growing as it does in a location where the water supply is poor, *Townsendia* would not require very extensive water-conducting tissues.

5. *Food-conducting Tissues.*—Longitudinally there seems to have been made very little provision for the conduction of

food in the stem. The phloëm portion is very little differentiated; it consists only of cambiform cells and undivided mother cells of the sieve tubes, there being found neither sieve tubes nor sieve parenchyma cells.

6. *Storage Tissues.*—Since *Townsendia* grows in a xerophytic habitat it is not surprising to find in it some provision for the storage of water. In the stem, the cortex, medullary ray and pith cells are well adapted to the storing of water. In the leaf, however, special provision is made: throughout the whole length of the leaf are found large water-storage cells which not only reduce transpiration but also rapidly fill whenever the water supply is increased, and yield their contents to the assimilating cells as the supply of water there is reduced.

7. *Aërating Spaces.*—As would be expected to be found in a xerophyte, the amount of space devoted to aëration is comparatively small. Only one one hundred and twenty-fifth of the volume of the leaf of *Townsendia* is devoted to aëration; while in *Pistia* about two-thirds of the volume of the leaf is thus employed.

LESQUERELLA SPATULATA.

Lesquerella spatulata is perennial by a much branched caudex which varies from one to two inches in length. It has a taproot which measures from one foot to a foot and a half in length and one-fifth of an inch in diameter at its thickest portion. The leaves are separated by short internodes and appear tufted. They measure from one-half to one inch in length and one-fifth to one-seventh of an inch in width. They are entire and vary in form from narrowly elliptic to ovate-lanceolate, oblanceolate and spatulate, and they, as well as the pedicels, are beset with stellate hairs. The flowers are yellow and are borne on pubescent scapes which measure from one-half inch to six inches in length.

The Stem.

The Tegumentary Tissues.—The protection of the mature stem is provided for by a cutinized epidermis and cork. There is, in addition to these tissues, in older portions of the stem, a borke. All of the walls of the epidermis are cutinized. Figure 37 represents a small portion of the epidermis as seen in cross

section; figure 38*a*, a small portion of the epidermis as seen in longitudinal section.

In the following table is given the average thickness of the cell walls and the average length and width of the epidermal cells:

Outer tangential wall	0.0049 mm.
Inner tangential wall	0.0049
Radial wall	0.003
Vertical diameter of cavity	0.075
Radial diameter of cavity	0.026
Tangential diameter of cavity	0.04

In the following table is given the average radial breadth of the cork zone, the average thickness of the walls of the cork cells, and the vertical, radial, and tangential dimensions of the cell cavity:

Average breadth cork zone	15-20 cells.
Average thickness of wall	0.001 mm.
Vertical diameter of cavity	0.025
Radial diameter of cavity	0.026
Tangential diameter of cavity	0.036

Figure 38*b* represents a few cork cells as seen in cross section.

In addition to this large zone of cork there are found in the borke rather large stone cells, which, as shown in figure 39, have relatively thick and pitted walls.

The tegumentary tissues are remarkably well developed for such a low, herbaceus plant as *Lesquerella*. When, however, its xerophytic habitat is taken into consideration, the necessity for this provision is readily seen.

The Strengthening Tissues.—The strengthening tissues in the stem consist of collenchyma, bast fibers, stone cells and wood fibers.

The radial breadth of the collenchyma zone is 0.093 mm. The average thickness of the walls of the collenchyma cells is 0.006 mm.; the average tangential breadth of the cell cavity is 0.036 mm.; the average radial thickness is 0.01 mm. In figure 40 are shown a few collenchyma cells as seen in cross section; in figure 41 as seen in longitudinal section.

The sclerenchyma tissue is made up of cells which vary from stone cells to short bast fibers. As shown in figure 42, the stone cells found here are smaller than those found in the borke. Figure 43 represents the stone cells as they appear in longitudinal section.

The bast fibers are 0.11 mm. long and 0.016 mm. wide, the average thickness of the cell wall being 0.006 mm. As may be seen in figure 44, the ends of the fibers overlap but little. In figure 45 are shown a few bast fibers as seen in cross section.

The most striking characteristic of the strengthening tissues of the stem is the presence of large zones of thick-walled wood fibers, which constitute 26 per cent of the area of the stem and 78 per cent of the area of the xylem. These wood fibers, as shown in figure 46, occur among spiral tracheal tissues. They average 0.11 mm. in length and 0.01 mm. in width. The walls are remarkably thick—0.006 mm.; the cell cavity is exceedingly small, in some places being almost entirely obliterated. Figure 47 represents a wood fiber as seen in longitudinal section.

The strengthening system in the stem of *Lesquerella* is more extensively developed than that in the stem of *Townsendia*, the only strengthening tissues found in the stem of *Townsendia* being collenchyma and short sclerenchyma cells, bast fibers and wood fibers being absent. This deficiency in *Townsendia*, however, is compensated by remarkably thick cell walls, not only of the strengthening tissues but of nearly all the tissues. The strengthening tissues in the stem of *Lesquerella* are so well developed that there is no need of the other tissues being modified, as was the case in the stem of *Townsendia*.

The Tracheal Tissues.—The tracheal system in the stem of *Lesquerella* consists of spiral and scalariform tracheal tubes and spiral and scalariform tracheids alone. There was found devoted to the conduction of water 2 per cent of the stem cross section, where the area was 7 sq. mm.; 4 per cent of the xylem, where the cross section area was 3.46 sq. mm., was devoted to this purpose.

In the following table is given the average thickness of the cell wall, and the average tangential and radial dimensions of the cell cavities of the various tracheal elements found in the stem of *Lesquerella*:

	Average thickness of cell wall.	Radial diameter of cavities.	Tangential diameter of cavities.
Largest tracheal tubes	0.002 mm.	0.016 mm.	.....
Smallest tracheal tubes	0.003	0.002	.....
Tracheids	0.002	0.016	0.04 mm.

As shown in figure 46—a small portion of the xylem as seen in cross section—the tracheal elements occur among alternating, definite zones of wood fibers, *A*, and wood parenchyma

cells, *B*, the largest ones being among the wood fibers and the smallest among wood parenchyma cells. It is generally conceded that spiral vessels are formed by the procambium exclusively, and wood fibers by the cambium. As the tracheal elements found interspersed among the wood fibers are spiral and scalariform, the activity here must be due either to the cambium or procambium. From the fact that these spiral vessels are found somewhat remote from the pith, there follows a probable conclusion that the cambium, contrary to the general rule, has formed spiral vessels.

The tracheal elements found in the stem at the nodes were different from those in the internodes. At the nodes the tracheal tissues consist exclusively of short and peculiarly shaped tracheids. In figure 48, *A*, are shown the scalariform type of tracheids; *B*, the spiral type of tracheids as seen in longitudinal section.

In the internodes the tracheal elements consist exclusively of spiral and pitted tracheal tubes, with the exception of a few tracheids interspersed here and there. Figure 49, *A*, illustrates the spiral tracheal tubes found among the wood fibers, as seen in longitudinal section; figure 49, *B*, spiral tracheal tube found among the wood parenchyma cells; figure 49, *C*, pitted tracheal tubes as seen in longitudinal section.

Tissues for the Conduction and Storage of Food.—The medullary rays found in the stem of *Lesquerella* present an interesting characteristic. Throughout the entire length of the medullary ray are found leaf traces containing spiral tracheal tubes as shown in figure 51, *a*. These tracheal tubes are much smaller than those found in the xylem area of the stem, the average diameter of the cavity being 0.007 mm. and the average thickness of the cell wall 0.002 mm. Figure 50, *a* represents a leaf trace. The internodes are so short that it is impossible to cut a section without having leaf traces traversing the medullary rays. These leaf traces run horizontally into the primary xylem, and when the cambium begins its activity it builds up the medullary rays around them. The average width of a medullary ray is 0.06 mm., and the average vertical length of a medullary-ray cell is 0.03 mm., and its average width is 0.01 mm. Figure 51, *b* represents a small portion of the medullary ray as seen in cross section.

In the stem, the ordinary collateral vascular bundles are

found; 20 per cent of the vascular bundle is devoted to phloëm, as in *Townsendia.* Neither seive tubes nor seive parenchyma cells are found. The whole work of conduction is assumed by the undivided mother cells of the sieve tubes. *Lesquerella* is a very low plant and it seems that the food can be conducted longitudinally fast enough and in sufficient quantities without the aid of the other phloëm elements. In figure 51, *c,* are shown a few phloëm cells as seen in cross section; in figure 52, as seen in longitudinal section; at the angles of these cells occur small intercellular spaces, *A.*

In the stem of *Lesquerella* the storage of food is provided for by means of the thin-walled parenchyma of the cortex and the xylem parenchyma and the medullary rays. Figure 53 represents a few cells of the thin-walled parenchyma of the cortex as seen in cross section. Figure 54 represents a few cells of the xylem parenchyma as seen in longitudinal section. In all of these tissues starch and proteid were found in small quantities, but neither sugar nor oil.

Figure 50 is a diagrammatic drawing of the cross section of the stem traced as seen when projected upon a screen. From this may be derived a general idea of the various tissues of the stem, their relation to one another, and the proportion of the stem devoted to each: *A,* borke; *B,* collenchyma; *C,* sclerenchyma; *D,* phloëm; *E,* xylem; 1, tracheal tissues; 2, wood fibers; 3, xylem parenchyma; *F,* medullary ray; *a,* leaf-trace.

The Root.

The Tegumentary Tissues.—The tegumentary tissues of the mature root consist of a cutinized epidermis and cork tissue which are similar to those tissues found in the stem, both in structure and proportion.

The Strengthening Tissues.—The strengthening tissues found in the root of *Lesquerella* consist of collenchyma, stone cells and wood fibers. These tissues show no difference whatever from those found in the stem.

The Tracheal Tissues.—The tracheal tissues in the root consist entirely of scalariform and spiral tracheal tubes. In a root where the cross section area was 18.75 sq. mm., there was found devoted to the conduction of water 4 per cent. Here the cross-section area of the xylem is 6.7 per cent of the entire root.

In the following table is given the average diameter and the

average thickness of the cell walls of the tracheal elements in the root:

Average diameter of the larger tracheal tubes	0.03	mm.
Average diameter of the smaller tracheal tubes	0.007	
Average thickness of cell wall	0.005	

As in the stem the tracheal elements of the root are interspersed among definite, alternating layers of wood fibers and wood parenchyma cells. Figure 55 represents a few wood fibers and tracheal tubes as found in the outermost layer of xylem (fig. 56*a*, *E*) as seen in cross section. Here the tracheal tubes are relatively large and the wood fibers have comparatively large cavities. The next succeeding layer of xylem (fig. 56*a*, *F*) consists of very small, thick-walled tracheal tubes, *A*, and wood parenchyma cells, *B*, shown with greater magnification in figure 57. In figure 58 are shown a few wood parenchyma cells as seen in longitudinal section. The average length of these cells is 0.07 mm. and the average width 0.015 mm. Figure 59 represents a few wood fibers and tracheal tubes found in the next succeeding layer of xylem (fig. 56*a*, *G*). The average diameter of the tracheal tubes in this layer of xylem is 0.023 mm.; here the wood fibers have remarkably thickened walls and a smaller cavity than those found in the outermost layer of xylem (fig. 56*a*, *E*).

Figure 56*a*, a segment of the cross section of the root, shows the constitution of the xylem: *A*, wood fibers; *B*, tracheal elements; *C*, wood parenchyma.

In figure 56*b* are shown the tracheal elements found in the root: *A* and *B*, scalariform tracheal tubes, *C*, spiral tracheal tube.

Tissues for the Conduction and Storage of Food.—In the root are found only secondary medullary rays, which are narrower than those found in the stem. In these medullary rays is found no tracheal system as in those of the stem. As in the stem, there seems to have been made very little provision for the passage of food longitudinally. Yet, however, a larger proportion (25 per cent) of the vascular bundle of the root is devoted to phloëm than in the stem. The phloëm consists exclusively of undivided mother cells of the sieve tubes.

Starch and proteids in small quantities were found in the medullary rays and phloëm-parenchyma cells, but neither glucose nor oil. In the root of *Townsendia* there was found glucose, but neither starch, proteid nor oil.

In figure 60—a diagrammatic drawing of the cross section of the root traced as seen when projected upon a screen—are shown the different zones of tissues of which the root consists and their relation to one another: *A*, cork; *B*, collenchyma; *C*, stone cells; *D*, thin-walled parenchyma; *E*, phloëm; *F*, wood fibers; *G*, wood parenchyma; *H*, tracheal elements; *I*, medullary ray.

The Tegumentary Tissues.—The tegumentary tissues consist of an epidermis with trichomes. All the walls of the epidermis are cellulose except the outer tangential wall, which has a thin film of cutin on the outer portion. The outer and inner tangential wall each measures in thickness 0.006 mm., and the radial wall 0.003 mm. The average radial diameter of the cell cavity is 0.02 mm., the average tangential diameter 0.016 mm. On both sides of the leaf the epidermis is of the same character. Figure 61 represents a small portion of the epidermis: *a*, cutinized portion; *b*, cellulose portion. The trichomes are thickly distributed over both sides of the leaf, and must be quite effective in giving protection. The discussion of these trichomes will be taken up in connection with the water-storage system.

The Tracheal Tissues.—For the study of venation, a leaf was used which had been bleached by standing four or five hours in dilute hydrochloric acid and then two or three days in chloral hydrate. As shown in figure 62, there could be seen in this leaf one large central vein, *A*, running longitudinally throughout the length of the leaf and sending off near the center of the leaf two large lateral branches, *B*, and below the center the large branch, *G*. On either side of the midrib there are two prominent longitudinal veins, *C*. These primary veins send out other veins which branch in every direction and end abruptly, as shown at *D*. The average distance between the ultimate branches of the veins, *E* and *F*, is 0.16 mm., there being included within this area, on the average, twenty-five mesophyll cells. The phloëm consists only of undivided mother cells of the sieve tubes, whose average length is 0.16 mm. and width 0.006 mm. The xylem consists exclusively of spiral tracheary tracheids. The average diameter of the tracheids in the midrib is 0.006 mm., and the average diameter of those in the smaller veins is 0.003 mm. In the midrib, where the cross-section area is 0.015 sq. mm., 20 per cent is devoted to

the conduction of water. Figure 63 represents a small portion of the midrib as seen in longitudinal section: *A*, spiral tracheary tracheid; *B*, undivided mother cell of the sieve tubes.

The Photosynthetic Tissues.—The leaf of *Draba* is bifacial, that is, palisade cells occur on both sides of the leaf, which is from twelve to fifteen layers of cells thick. The average radial length of a palisade cell is 0.027 mm., the average cross diameter 0.02 mm. Figure 64 represents a few palisade cells as seen in surface view.

The average number of chloroplasts in a single mesophyll cell on either side of the leaf is twenty-seven. The small number of chloroplasts found in the mesophyll cells of the upper side of the leaf allows the sunlight to penetrate to the lower side, thus giving to the cells there the power to carry on photosynthesis effectively.

The Water-storage Tissues.—In the leaf of *Lesquerella* there are no water-storage cells as are found in that of *Townsendia*. The only structures in the leaf that might serve principally as water-storage elements are the large trichomes which occur on both sides of the leaf. These trichomes, as shown in figure 65 (surface view) are quite frequent, and are stellate-peltate in form. These, as a rule, are found above a vein, and, since they are alive even on old leaves, they presumably have some active function to perform. Their basal portion is slightly depressed beneath the lower level of the epidermis, and the wall here is cellulose. The remaining portion of the wall of the trichomes is cellulose, except the very outer portion, which is cutinized. The fact that these trichomes occur above the veins and that their basal portion is cellulose-walled seems to point to the conclusion that when there is plenty of water furnished by the veins they absorb water, store it up, and yield it to the mesophyll cells as it is needed. Figure 66 represents a trichome as seen in a leaf cross section: *A*, cutinized portion of a wall of trichome; *B*, cellulose portion of wall of trichome; *C*, mesophyll cells; *D*, tracheids.

The Aërating Spaces of the Leaf.—Mounting the bleached leaf so that it could be looked through from surface to surface, I estimate that approximately 2.7 per cent of the volume of the leaf is devoted to intercellular spaces; in other words, the volume of the intercellular spaces and the volume of the whole leaf, roughly estimated, stand in relation to each other as

27 : 1000. On either side of the leaf are found 640 stomata to 1 sq. mm., a much larger number than was found in the leaf of *Townsendia*. The stomata are at the surface of the leaf instead of being sunken, as is often the case with xerophytes. In figure 67 are shown a few stomata as seen in surface view. In figure 68 is shown a stoma as seen in cross section.

Figure 69 represents a small portion of a leaf as seen in cross section: *A*, upper epidermis; *B*, lower epidermis; *C*, palisade tissue; *D*, vascular bundle.

SUMMARY.

1. *Size and Habit of Lesquerella spathulata.*—*Lesquerella spathulata*, a perennial from a branched caudex, is a low plant growing from one to two inches high. It was found growing on a rocky clay bluff, occurring not as isolated individuals, but in colonies.

2. *Tegumentary Tissues.*—In the mature stem of *Lesquerella* the tegumentary tissues consist of a cutinized epidermis, cork, and borke. In the mature root the tegumentary tissues consist of a cutinized epidermis and cork.

The tegumentary tissues of the leaf consist of an epidermis, all the walls of which are cellulose except a thin film of cutin on the outer tangential wall. There is, in addition to the ordinary epidermal cells, stellate trichomes on both sides of the leaf, which would be effective in protection against too intense illumination and in the reduction of transpiration, as well as in the storage of water.

3. *The Strengthening Tissues.*—The strengthening tissues consist of collenchyma, bast fibers, stone cells and wood fibers. The wood fibers constitute a very important part of the strengthening system. These have remarkably thickened walls, the cavities in some cases being almost obliterated. Contrary to the general rule, the wood fibers are found among spiral tracheal tubes, both wood fibers and spiral tracheal tubes having been formed by the cambium.

4. *Tracheal Tissues.*—The tissues devoted to the conduction of water constitute 2 per cent of the stem and 4 per cent of the root. This seems a comparatively small area devoted to this purpose, but growing, as *Lesquerella* does, in a location where the water supply is poor, it would not require very extensive

water-conducting tissues. The tracheal tissues consist of spiral and scalariform tracheal tubes and tracheids.

5. *Photosynthetic Tissues.*—The photosynthetic tissues of the leaf consist exclusively of palisade cells, and there is found in a single palisade cell on either side of the leaf an average of twenty-seven chloroplasts.

6. *Food-conducting Tissues.*—As in *Townsendia,* the phloëm is but little differentiated. It consists exclusively of undivided mother cells of the sieve tubes; sieve tubes and sieve parenchyma cells are wholly lacking.

7. *Storage Tissues.*—In the stem the phloëm cells and medullary-ray cells afford provision for the storage of food. In these tissues starch and proteids were stored up in small quantities. The only storage tissues found in the leaf are the large stellate hairs which, possibly, rapidly fill whenever the water supply is increased, and, being cellulose-walled at their bases, yield their contents to the mesophyll cells as the supply of water is reduced.

8. *Aërating Spaces.*—As would be expected to be found in a xerophyte, the amount of space devoted to aëration is comparatively small, there being only 2.7 per cent of the volume of the leaf devoted to this purpose.

PLATE I.

A. Dakota sandstone resting on Permian shales. Man's head in line with contact. Spring creek, six miles north of Washington.

B. Unconformity of Pleistocene on Permian. Ravine running from left to right in Permian shales with thin limestone forming the top crosses a buried gully at right angles to it filled with Pleistocene material, which is etching backward. Note the tipping of the limestone into the old gully (undisturbed by recent erosion). About three miles east of Washington.

The University of Chicago Library

PLATE II.

A. Unconformity of Dakota on Permian sandstone at contact projects. Brickyard, east side of Smoky Hill river, Salina.

B. Same. South end of same hill by old mill.

The University of Chicago Library

PLATE III.

A. Cliff of Dakota sandstone. East side of Mill creek, northeast of Washington.

B. Slumping of soft sediments, clays apparently of Dakota age. Three miles east of Washington.

The University of Chicago Library

PLATE IV.

A. Slumped soft Dakota clays surrounded by impure sandstone, on Permian floor. Three miles east of Washington.

B. Alfalfa field on the wide terrace of the Republican river, west of Clay Center.

The University of Chicago Library

PLATE V.

FIG. 1.—View looking southwest from ruins, showing heavy ledges of Loup Fork rock in background, from which the pueblo was built. In the foreground two of the party are shown excavating one of the circular pits which occur about twenty yards north of the main building.

FIG. 2.—Ground plan of ruins, showing remains of the division walls, looking west. Remains of the mealing trough shown in the extreme corner of room I, to the left of the observer. To the right, in room V, the small fireplace built into the wall can be seen.

The University of Chicago Library

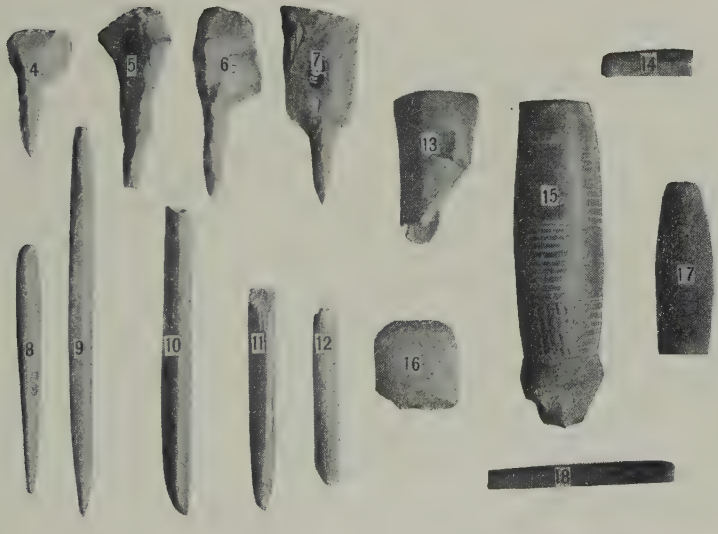
PLATE VI.

FIG. 3.—Typical Pueblo grinding trough, three feet nine inches long by two feet one inch wide and eighteen inches deep.

FIGS. 4, 5, 6, 7.—Awls or drills, used principally for perforating skins and boring holes into bones, etc. Figure 7 is of a reddish flint, beautifully colored, and of fine workmanship.

FIGS. 8, 9, 10, 11, 12.—Bone implements, probably used to enlarge holes in skins. Have been much used.

FIGS. 13 to 18, inclusive.—Pipes and pipe stems; all are made of native clay. Figure 15 is well made and is decorated with the design shown on plate VIII, figure 62; mouthpiece broken off. Pipe measures two and one-half inches long and seven-eighths inch in diameter at the center.



University of Chicago Library

PLATE VII.

FIGS. 19, 20, 21, 22, 23, 24.—Arrow shaft straighteners. These are made of the Dakota sandstone, and probably came from somewhere in the vicinity of Quivira, for no outcroppings of this material are exposed nearer to Quartelejo than those which occur on the western boundary of Brower's Quivira, about 130 miles east of the Quartelejo pueblo.

FIG. 25.—Bone piccolo, made from the wing bone of a large bird, probably a pelican.

FIG. 26.—Bone implement, possibly a hoe blade, from shoulder blade of buffalo.

FIG. 27.—Tallying implement, made from rib of buffalo.

FIG. 28.—Bone tool with a toothed edge, which may have been used for fleshing skins.

FIG. 29.—Bone tool, made from rib of buffalo, worn smooth and flat, spatula-like.

FIG. 30.—Bone implement of undetermined use, much worn, with toothed edge. Made from shoulder blade.

FIGS. 43 to 56, inclusive.—Fleshers or scrapers, of flint. Figures 43, 45, 46, 47, 51, 52, are beautifully made. Figures 46 and 51 show cross sections of *Fusilina*, a fossil typical of the Carboniferous. The material of these two, at least, is not found in the vicinity of the ruins, and was probably procured from the eastern part of the state.

The University of Chicago Library

PLATE VIII.

FIGS. 57, 58.—Knife blades of yellow chert.

FIG. 59.—One of the most interesting implements found, consisting of the half of an iron ax head, five and one-half inches long by one and a quarter wide at its greatest width, and five-eighths of an inch thick. This, by some mischance, had been split in two longitudinally, and was arranged with a groove around it instead of an eye like our modern axes have.

FIG. 60.—A fine grinder of conglomerate, eleven inches long. Shows much usage.

FIG. 61.—The half of a clam shell, plainly showing saw-tooth marks where it was divided. This was found at the bottom of the twelve-inch hole in room V.

FIG. 62.—Diagram of pattern on pipe bowl shown on plate VI, figure 15. Impression was made on clay and photographed.

FIG. 63.—Base of deer antler, which has evidently been used as some implement.

FIGS. 64 to 69, inclusive.—Specimens of charred corncobs. Figure 59 shows some well-developed kernels on it.

FIG. 70.—Bone implement, well worn.

FIG. 71.—Portion of 'dobe plastering from walls, showing impressions of finger tips.

FIG. 72.—Baked clay marble, evidently used in some game.

FIGS. 73, 74, 75.—Chert scrapers.

FIG. 76.—Hoe blade made from shoulder blade of buffalo.

The University of Chicago Library

PLATE IX.

FIG. 77.—Small metate or grinder, of sandstone.

FIG. 78.—Grinder made of clay mortar and coarse sand, and baked as hard as rock itself.

FIG. 79.—Hammer worked from a glacial boulder; well made and much worn.

FIG. 80.—Grinder, of very fine granite.

FIG. 81.—Grinder, of material same as figure 78.

FIG. 82.—Grinder, made from glacial boulder.

FIGS. 83, 85.—Grinders, of fine sandstone.

FIG. 84.—Knife blade of chert.

The University of Chicago Libr

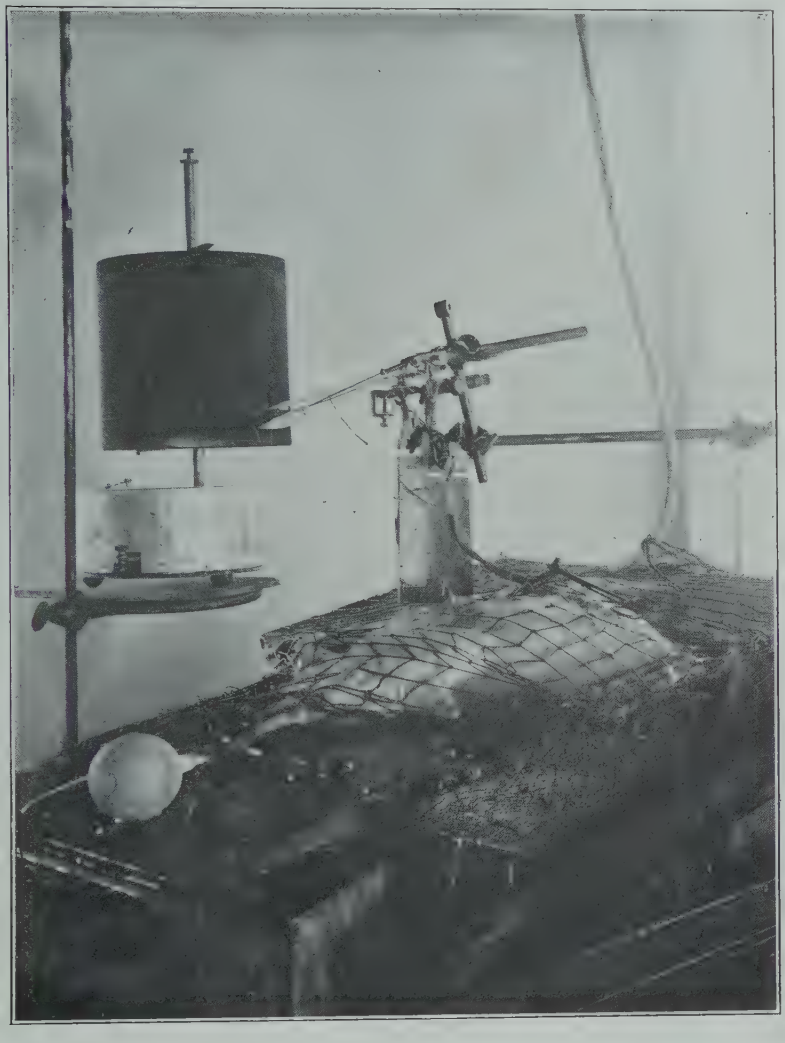
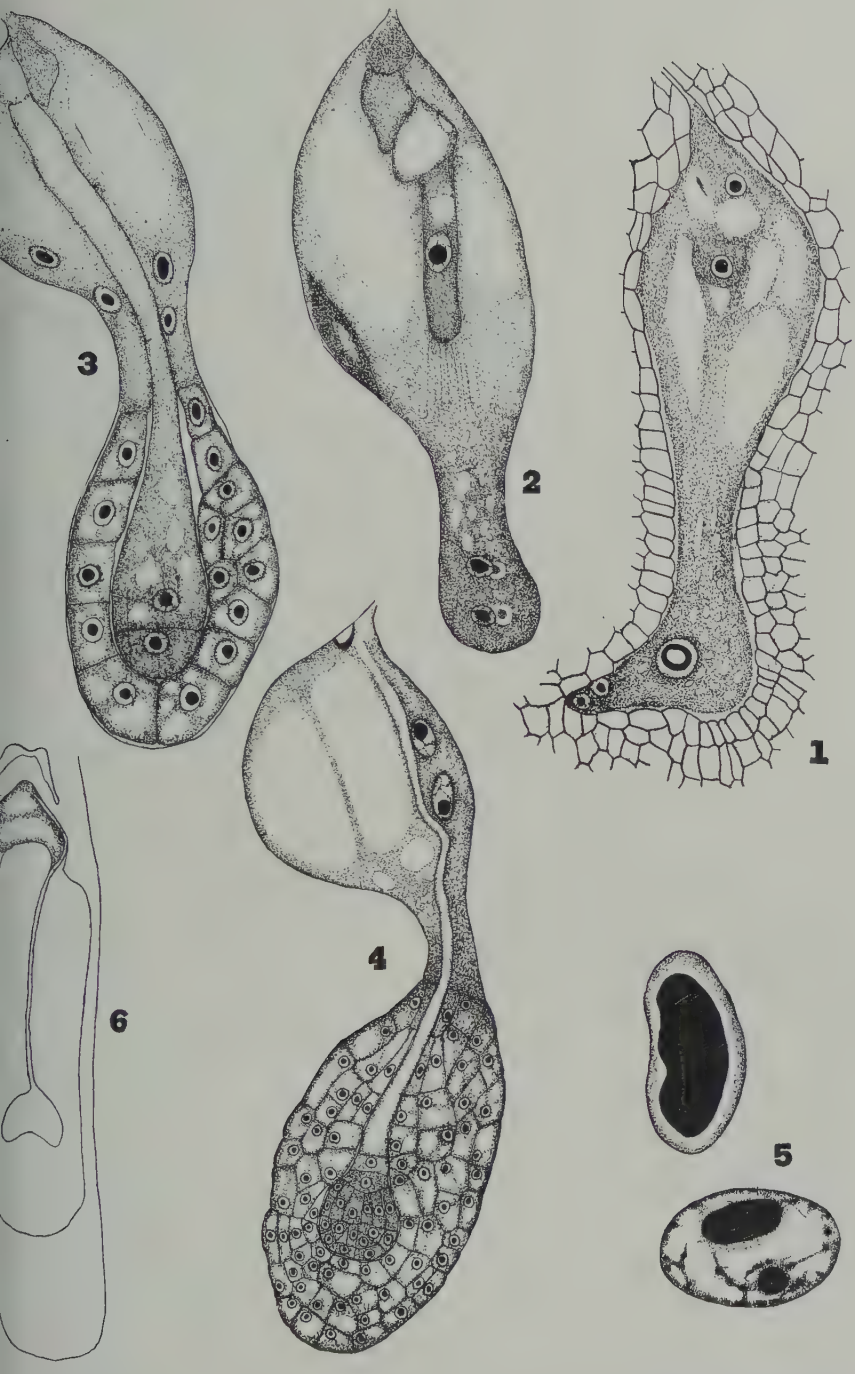
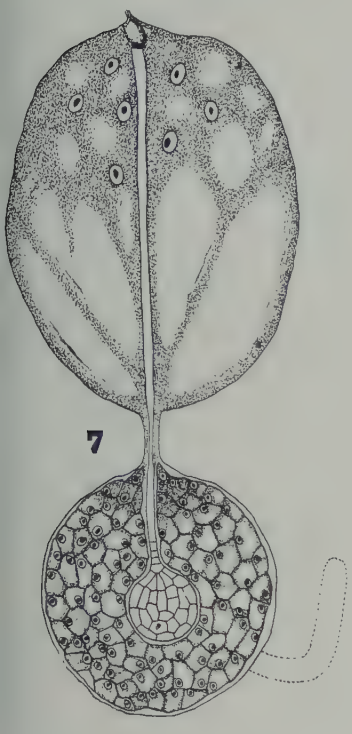


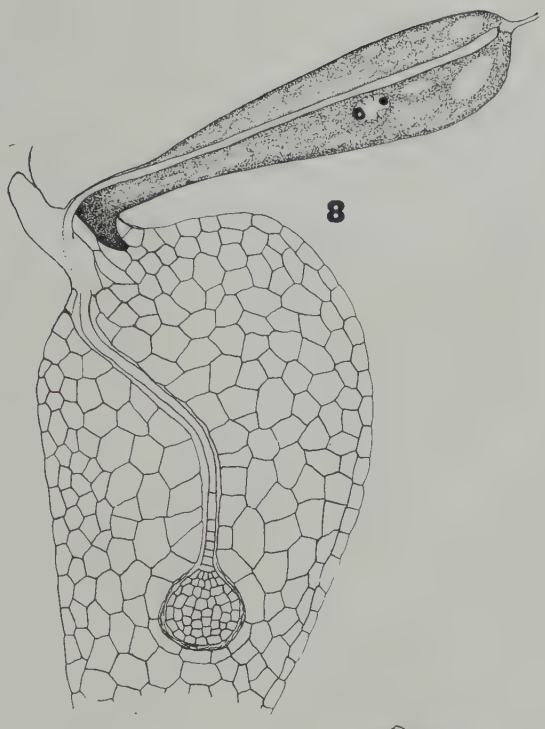
PLATE XI.



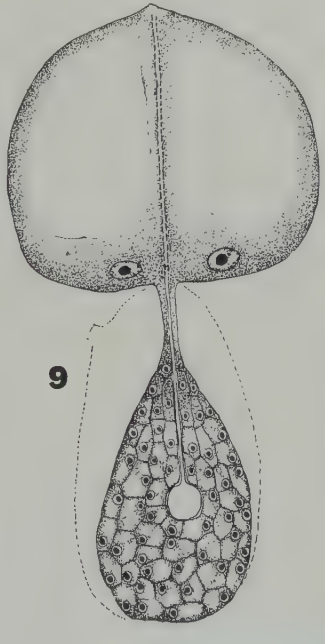
The University of Chicago Library



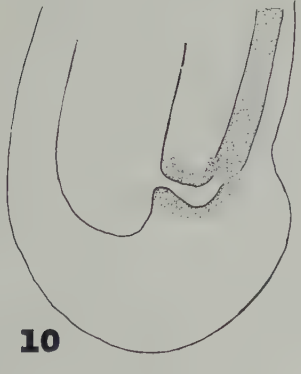
7



8



9

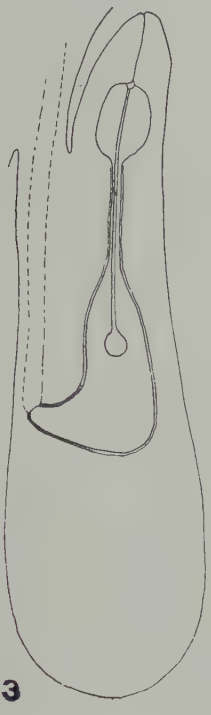


10

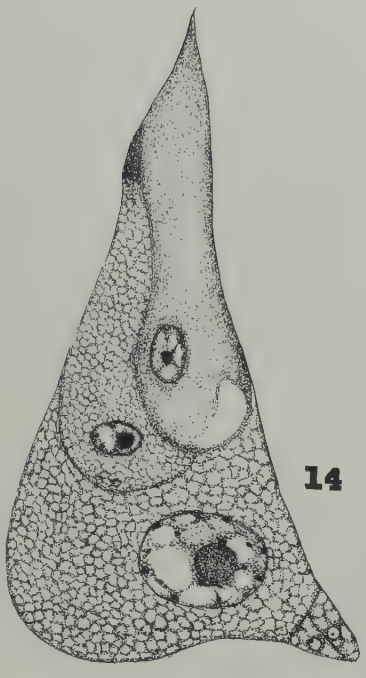
11

The University of Chicago Library

12

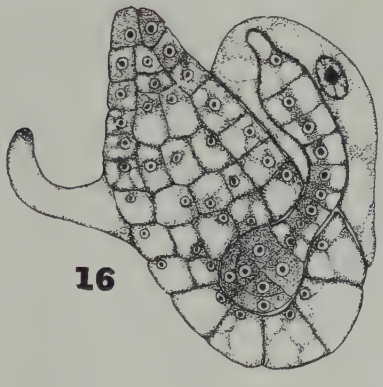


13

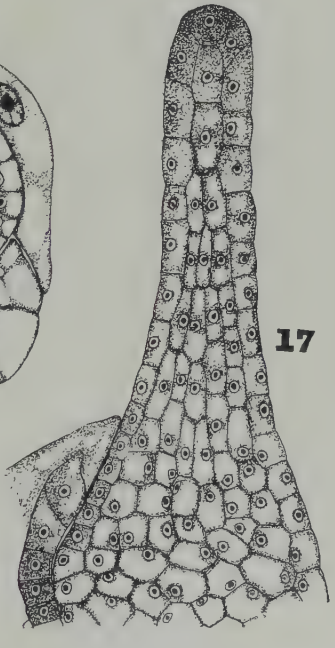


14

15

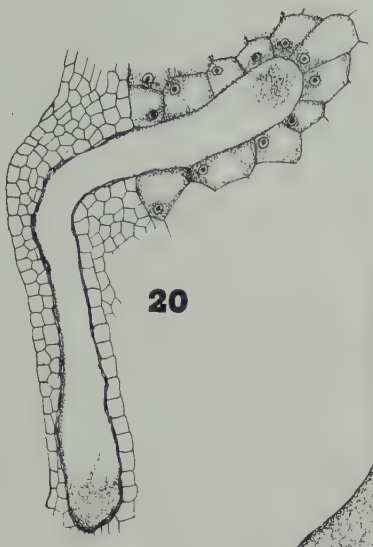


16

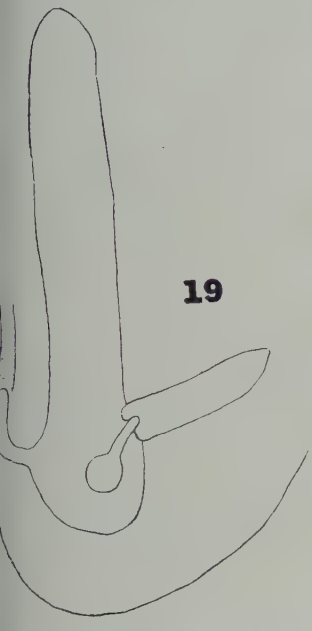


17

The University of Chicago Library

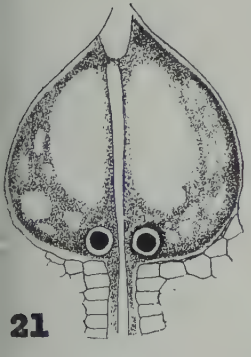


20



19

18



21

22

23

The University of Chicago Library

PLATE XV.

FIG. 1. Two resting cells, showing chromatin granules, and nucleoli with the surrounding clear space.

FIG. 2. Cell beginning mitosis. Close spireme. Nucleoli without the clear space.

FIG. 3. A granular spireme. The nuclear membrane has disappeared but the cytoplasm can still be distinguished from the nuclear sap.

FIG. 4. The chromatin granules are here arranged in rows. This cell has its nuclear membrane yet and the nucleoli have not disappeared.

FIG. 5. Polar view; spireme segmented to form the chromosomes, has a longitudinal split, and is uniformly granular. Nuclear wall just disappeared. Chromosomes looped to form U and J shapes.

FIG. 6. A little later than figure 5. The longitudinal split is very clearly seen.

FIG. 7. Late metaphase. Cytoplasm granular in places, may have been slight plasmolysis in this cell. The spindle fibers are stained very lightly here.

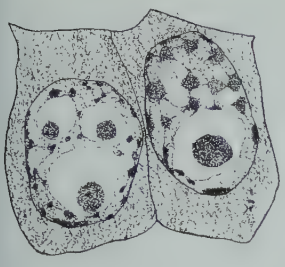
FIG. 8. Metaphase. Spindle shows marked polarity; chromosomes somewhat indefinite.

FIG. 9. Metaphase. Cytoplasm at the ends becoming vacuolated and at the center slightly denser. An especially long chromosome (*m*) is to be noted.

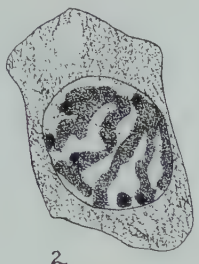
FIG. 10. The cytoplasm of this cell was crushed; however, the chromosomes, which were undivided yet, show the longitudinal split clearly.

FIG. 11. Anaphase. Cytoplasm very granular in places (homogeneous portion not shown). The spindle is well stained in this cell, and the chromosomes have their characteristic bent shape.

FIG. 12. Anaphase. Spindle not clear in this figure. The amount of cytoplasm is small compared to the amount of chromatin here.



1.



2

3

4

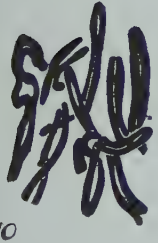
5

6

7

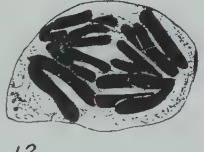
8

9



10

11



12

The University of Chicago Library

PLATE XVI.

FIG. 13. Anaphase. Massing of the cytoplasm at the center of the cell.

FIG. 14. Anaphase. The long chromosomes (*m*) are to be seen in this figure.

FIG. 15. Anaphase. Shows relation of chromosomes to spindle during this period.

FIG. 16. Anaphase. Spindle fibers do not show here; reticular cytoplasm (drawn from a slide loaned by Mr. Alban Stewart).

FIG. 17. Anaphase. Polar view; 14 chromosomes.

FIG. 18. Same as 17.

FIG. 19. Telophase. Shows the loosening up of the chromosomes. Cell plate beginning to form.

FIG. 20. Chromatin has diffused throughout the nucleus ahead of the cell-plate formation. A nuclear membrane has also been formed.

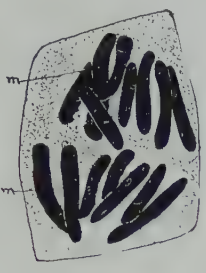
FIG. 21. Chromatin a dense mass, very indefinite at the ends of the cell, not shown; cytoplasm much contracted from the cell wall and concentrated about the spindle.

FIG. 22. A very peculiar spindle; cytoplasm much condensed; a second dense spindle formed about the center of the cell where the cell-plate is appearing. Chromatin not shown.

FIG. 23. Concentrated cytoplasm at the spindle center; a very broad spindle and the cell plate extends entirely across it. Cytoplasm vacuolated; the daughter nuclei, not shown in this figure, are nearly reconstructed.

FIG. 24. Cell plate nearly formed; nuclei reconstructed; cytoplasm concentrated at the center. (From slide belonging to Mr. Stewart.)

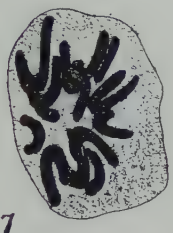
13



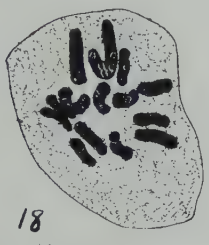
14

15

16

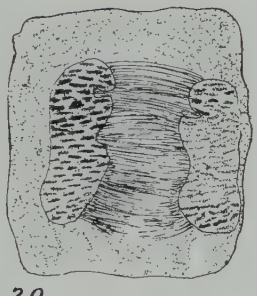


17



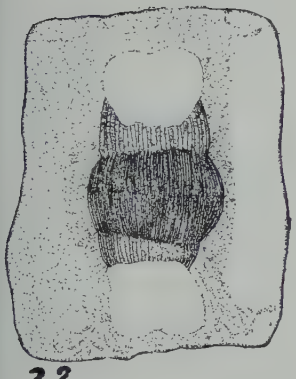
18

19

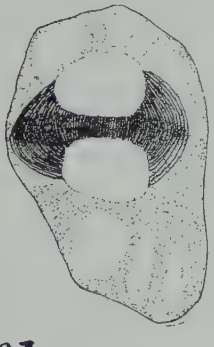


20

21



22



23

24

The University of Chicago Library

PLATE XVII.

Koeberlinia spinosa.

FIG. 1.—Branch of *Koeberlinia spinosa*. × about ½.

FIG. 2.—Aspect of vegetation on mesa near Tucson in the neighborhood from which the specimen was taken.
Photographs by L. M. Peace.

1

2

The University of Chicago Library

PLATE XVIII.

Koeberlinia spinosa.

FIG. 1. Cross section of stem. *P*, pith; *M*, medullary ray; *W*, wood; *Tr*, tracheal tubes of year '07 (?); *Ph*, phloëm; *Sa*, spongy parenchyma air space; *Pa*, palisade air space; *Ea*, epidermal air space; *B*, bast; *Scl*, sclerenchymatous tissue. Semi-diagrammatic. × 25.

FIG. 2. (*a*) Section from an older stem, showing traces of annual rings, '07, '05. (*b*) Portion of same stem, opposite side, showing '06 trace. Semi-diagrammatic. × 25.

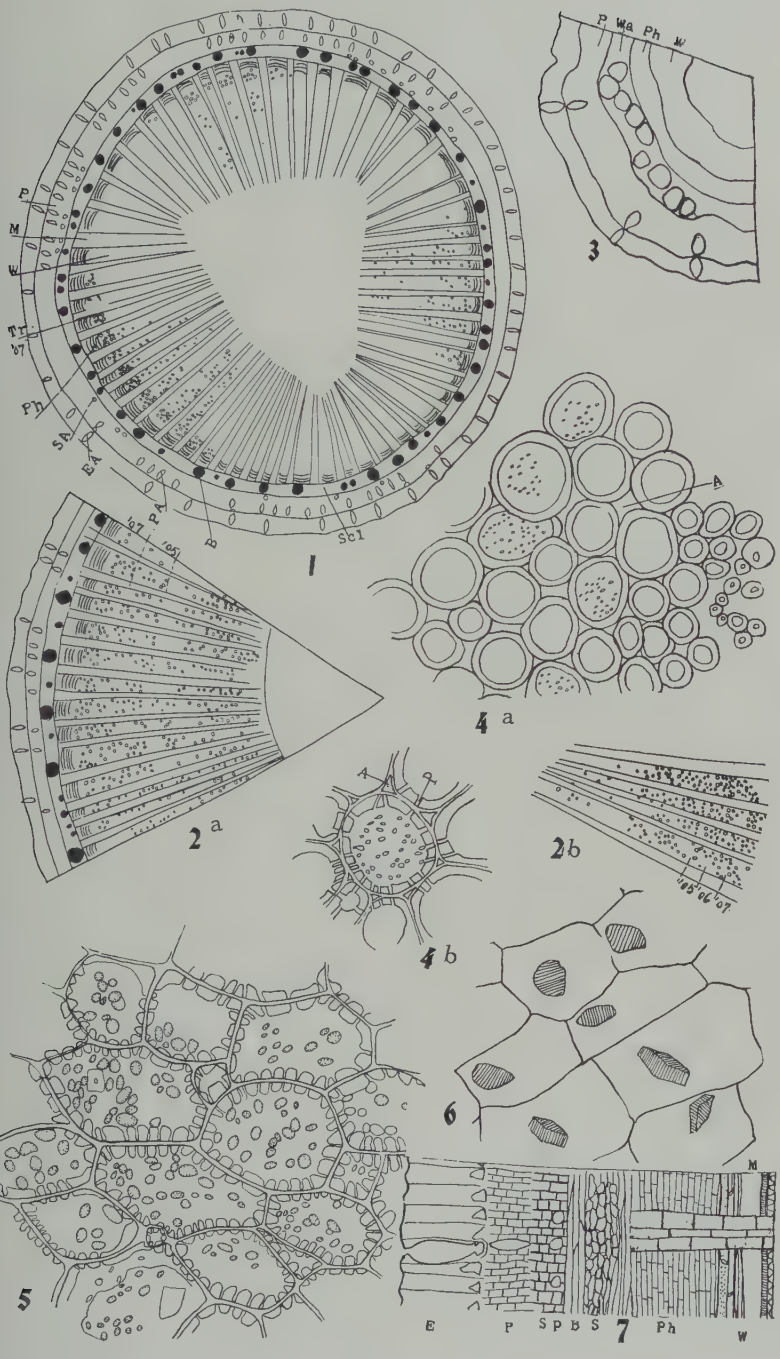
FIG. 3. Cross section of flower branch, showing region of *wa*, water storage cells. × 283.

FIG. 4. (*a*) Pith from flower branch, showing air spaces, *A*. Cross, × 283. (*b*) Single cell from flower-branch pith, showing pits, *P*; air spaces, *A*. Cross, × 400.

FIG. 5. Pith of old stem, showing pitted conditions and starch bodies. Cross, × 283.

FIG. 6. Crystals in old pith cells; longitudinal section. × 283.

FIG. 7. Diagrammatic representation of regions of older stem. *E*, epidermis; *P*, palisade; *Sp*, sponge; *B*, bast; *S*, stone cells; *Ph*, phloëm; *W*, wood. Enlarged.



The University of Chicago Library

PLATE XIX.

Koeberlinia spinosa.

FIG. 1. Medullary rays, showing longitudinal extension, longi-tangential section. Semi-diagrammatic. × 55.

FIG. 2. Portion of (1) in detail, showing thick walls, some pits, and numerous aerating places. Tangential. × 283.

FIG. 3. Single medullary ray cell from (2), showing food bodies *F, B;* pits, *P;* aerating spaces, *A*. Longi-tangential. × 636.

FIG. 4. Medullary ray cells, showing one elongated and narrow cell *e. c.*, and some more, box-like, for storage, *St*. Longi-radial, × 283.

FIG. 5. Single storage cell from (4), showing food bodies. Longi-radial, × 636.

FIG. 6. Portion of medullary ray extension in phloëm region, showing thin, unpitted walls and cells filled with nitrogenous material. Longi-radial, × 283.

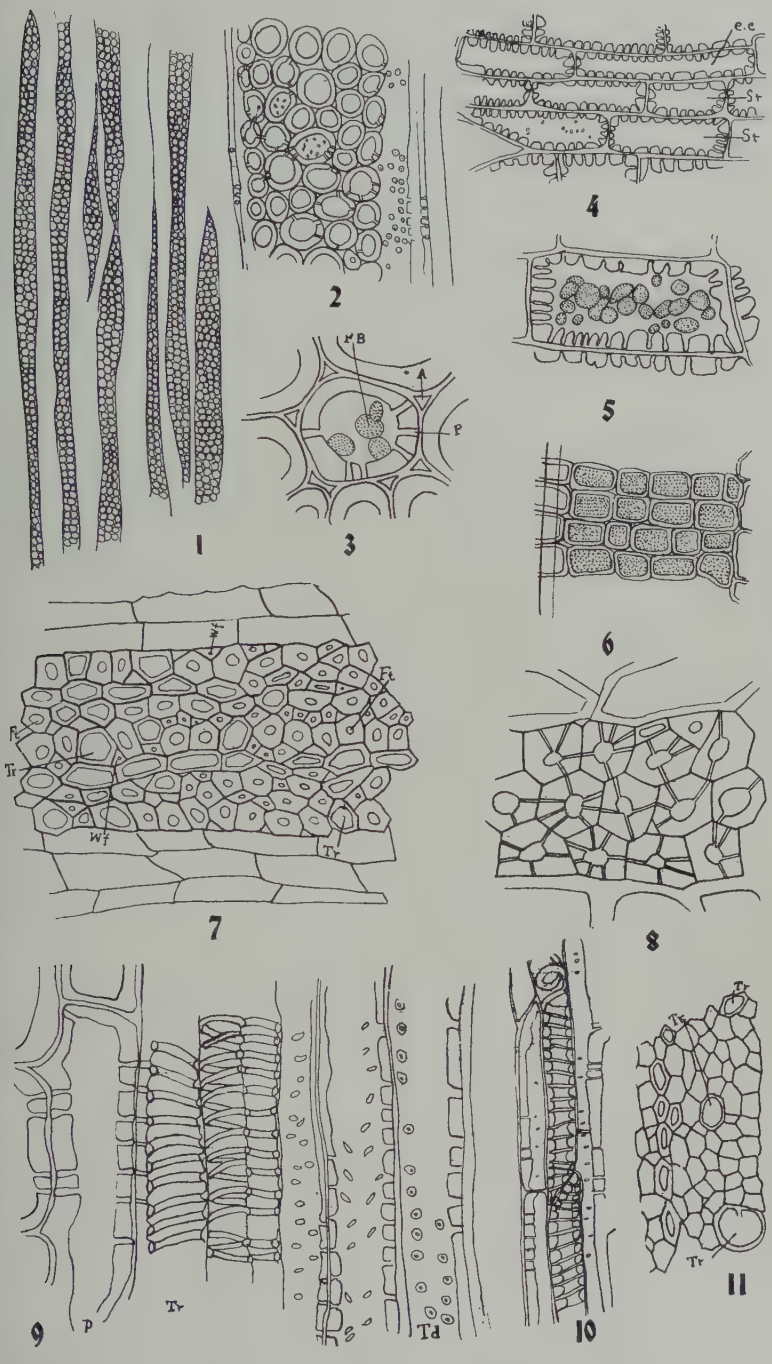
FIG. 7. Portion of older wood, showing tracheids, *Tr;* fiber tracheids, *Ft*, and wood fibers, *wf*. Cross, × 283.

FIG. 8. Detail of (7), showing pitted condition of wood. × 636.

FIG. 9. Water vessels bordering pith. *Tr*, tracheal tubes; *Td*, tracheid; *P*, pith. × 636.

FIG. 10. Spiral tracheids, near pith. Semi-tang., × 283.

FIG. 11. Portion of wood, showing scattered tracheids, *Tr*. Cross, × 283.



The University of Chicago Library

PLATE XX.

Koeberlinia spinosa.

FIG. 1. Tracheal tube bordering elongated pith cell, on margin of older part of bundle. *P*, pith cell; *Tr*, tracheal tube. Longi-radial, × 636.

FIG. 2. Elongated pith cells densely filled with finely granular food material. Pits in walls omitted. *P*, pith; *W*, wood. Longi-section, × 283.

FIGS. 3, 4, 5, 6. Different views of tracheal tubes, all showing the circular opening at the end. 6 (*a*) Third partition in tube 6, showing section of ring bordering aperture. These have become so completely welded as to give the appearance of a continuous tube, as in 6. Longi-section, × 400. Fig. 3 is the cavity outlined.

FIGS. 7, 8, 9. Sketches showing joining of ends of tracheids. Longi-radial, × 400.

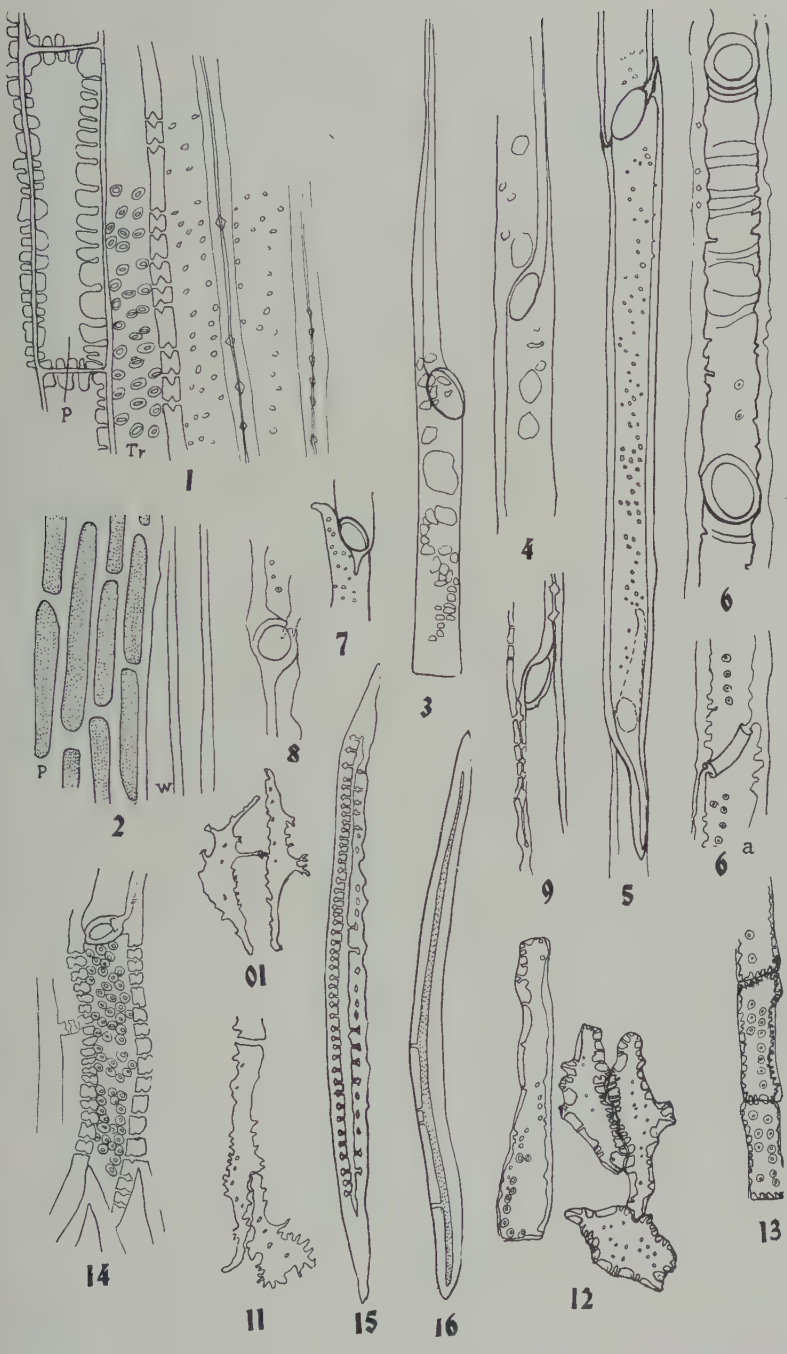
FIGS. 10, 11, 12. Various odd or malformed tracheids. Longi-radial, × 283.

FIG. 13. Regular rectangular tracheids. Longi-radial, × 283.

FIG. 14. Single tracheid. Longi-radial, × 283.

FIG. 15. Fiber-tracheid with small but numerous pits. × 283.

FIG. 16. Wood fiber. Longi-section, × 283.



The University of Chicago Library

PLATE XXI.

Koeberlinia spinosa.

FIG. 1. Five rows of phloëm parenchyma cells *p. p.*, as seen in cross section; *m*, medullary-ray cells. × 283.

FIG. 2. Sketch of portion of phloëm, *Ph*, region bordering stone cells, *S*, showing various sizes of cells. Longi-section, × 283.

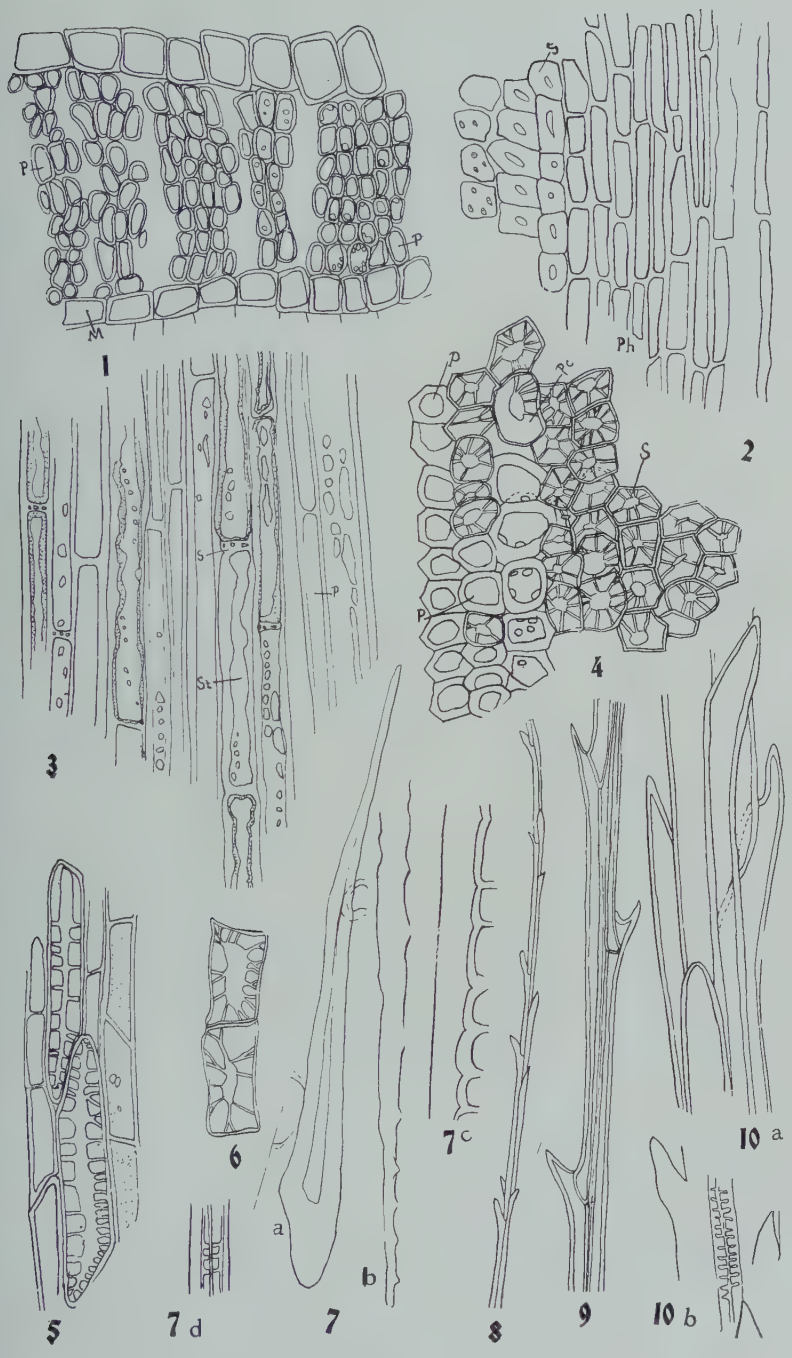
FIG. 3. Portion of (2) in detail, sieve tubes, *St.*, and sieve plates, *S*, and parenchyma cells alongside, *p*. Longi-section, × 400.

FIG. 4. Stone cells bordering spongy parenchyma, showing some cells unlignified, and some but partly lignified, parenchyma cells; *s*, stone cells; *pc.*, partly lignified; *P*, unlignified. Cross section, × 283.

FIGS. 5, 6. Different sizes and shapes of stone cells. Longi-section, × 283.

FIG. 7. (*a*) Tapering bast fiber. (*b*) Portion of long bast fiber, showing tapering part and projections of wall to support neighboring cells. (*c*) Projections with adjoining cellulose walls in detail. (*d*) Pits in long fiber. All × 283.

FIGS. 8, 9, 10*a*, × 55, 283, 636, respectively. Short bast fibers as they occur securely fastened together. 10*b*, sketch showing pits in short bast fiber, × 636.



The University of Chicago Library

PLATE XXII.

Koeberlinia spinosa.

FIG. 1. Portion of palisade *P*, and spongy parenchyma, *Sp*, tissue, from stone cells to epidermis. Numerous intercellular spaces *I. S.*, are found. Cross section, × 283.

FIG. 2. End view of palisade cells, showing number and size of chlorophyll bodies. Tangential section, × 283.

FIG. 3. Epidermis of young stem, showing large cellular space, *cs*, and thin walls; this also shows frequency of deeply sunken stomata, *ss*. Cross, × 283.

FIG. 4. Portions of older epidermis, showing reduction of cell space by intense cutinization; cell space, *cs;* cutinized portion, *cp*. Cross, × 283.

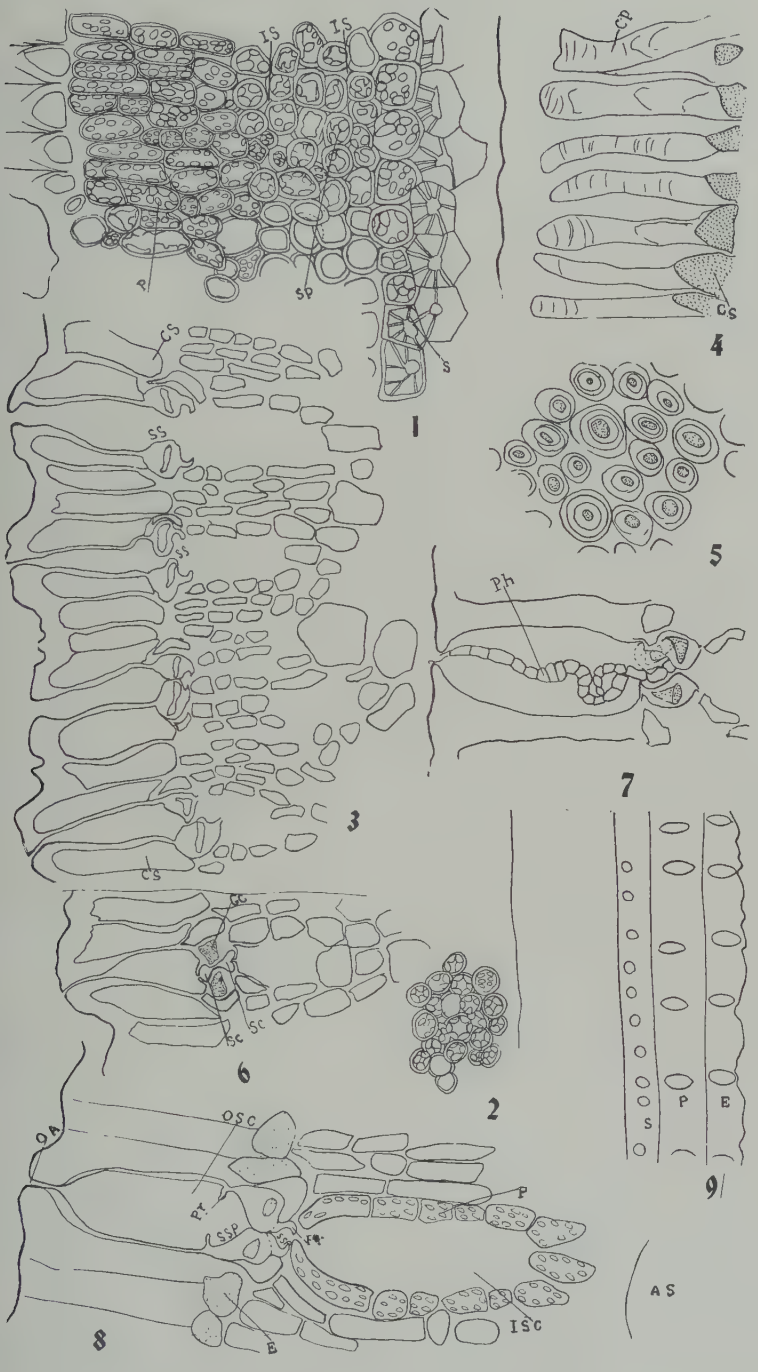
FIG. 5. Tangential view of older epidermal cells, showing thickening of walls. × 283.

FIG. 6. Single stoma from young stem, showing large guard cells, *Gc*. Also, small stomatal chamber proper, above and below, *sc*. Cross, × 283.

FIG. 7. Cuter stomatal chamber invaded by phycomycete, *Ph*. Cross, × 283.

FIG. 8. Stomatal apparatus. *OA, outermost aperture; E*, epidermal cell space; *osc*, outer stomatal air chamber; *isc*, inner stomatal air chamber; *Pr*, projection of thickening, making stomatal spaces proper, *ssp; P*, palisade cells; *AS*, air space in sponge. Cross, × 283.

FIG. 9. Outline of regions of aerating spaces, showing frequency of spaces. *E*, epidermal region; *p*, palisade region; *s*, sponge region. Enlarged.



The University of Chicago Library

PLATE XXIII.

Koeberlinia spinosa.

FIG. 1. *S*, stone cells filling up lower stomatal chamber; *Ph*, remains of Phycomycete in outer aperture; *d*, portion of "dome." Cross section, × 283.

FIG. 2. Surface view of outer stomatal aperture and epidermal cells. *SA*, stomatal aperture; *EC*, epidermal cells. Tangential section, × 283. Compare with fig. 3, plate XXII.

FIG. 3. View toward outer stomatal aperture from within, showing tips of cells making the "dome." Tangential section, × 283.

FIG. 4. Section across mid-chamber. Tangential, × 283.

FIG. 5. View looking toward stoma, showing shelf, *s*, made by projecting walls. Tangential, × 283.

FIG. 6. Stoma proper, showing guard cells. Tangential, × 283. Compare with fig. 6, plate XXII.

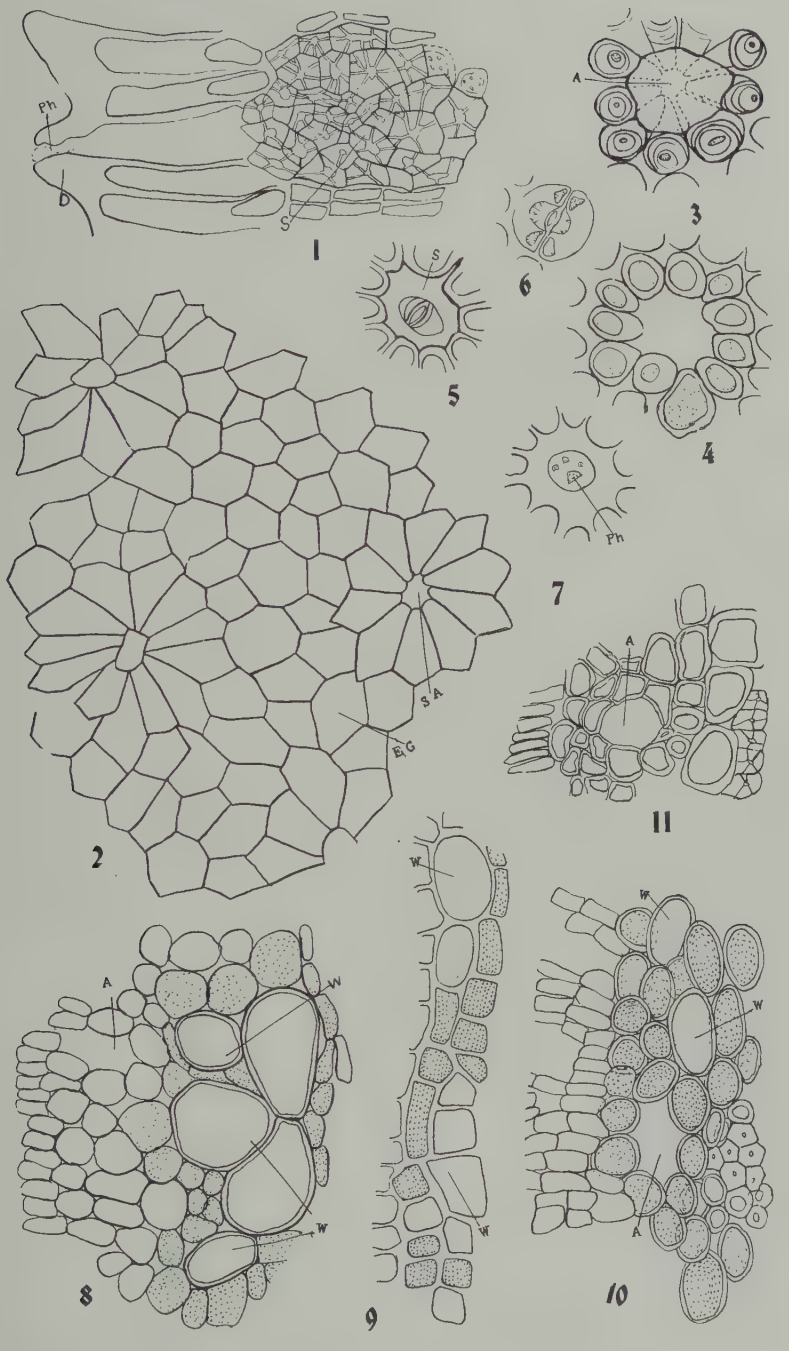
FIG. 7. Stoma proper, invaded by growth of Phycomycete, *Ph*. Tangential section.

FIG. 8. Water-storage cells, *W*, in flower branch, and aerating space, *A*. Cross, × 283.

FIG. 9. Portion of older stem, showing empty cells, *W*, probably for water storage. Cross, × 283.

FIG. 10. Water-storage cells, *W*, and aerating space, *A*, in flower branch. Cross, × 283.

FIG. 11. Aerating space, *A*, in spongy parenchyma. Longi-section, × 283.



The University of Chicago Library

PLATE XXIV.

FIG. 1. Resinous-gum cells, *RD*, surrounding vascular bundles in elongated portion of receptacle. Cross, × 283.

FIG. 2. Resinous-gum cells in elongated portion of receptacle, *RD*. Longi-section, × 283.

FIG. 3. Resinous-gum cells, *RD*, surrounding ovule. × 283.

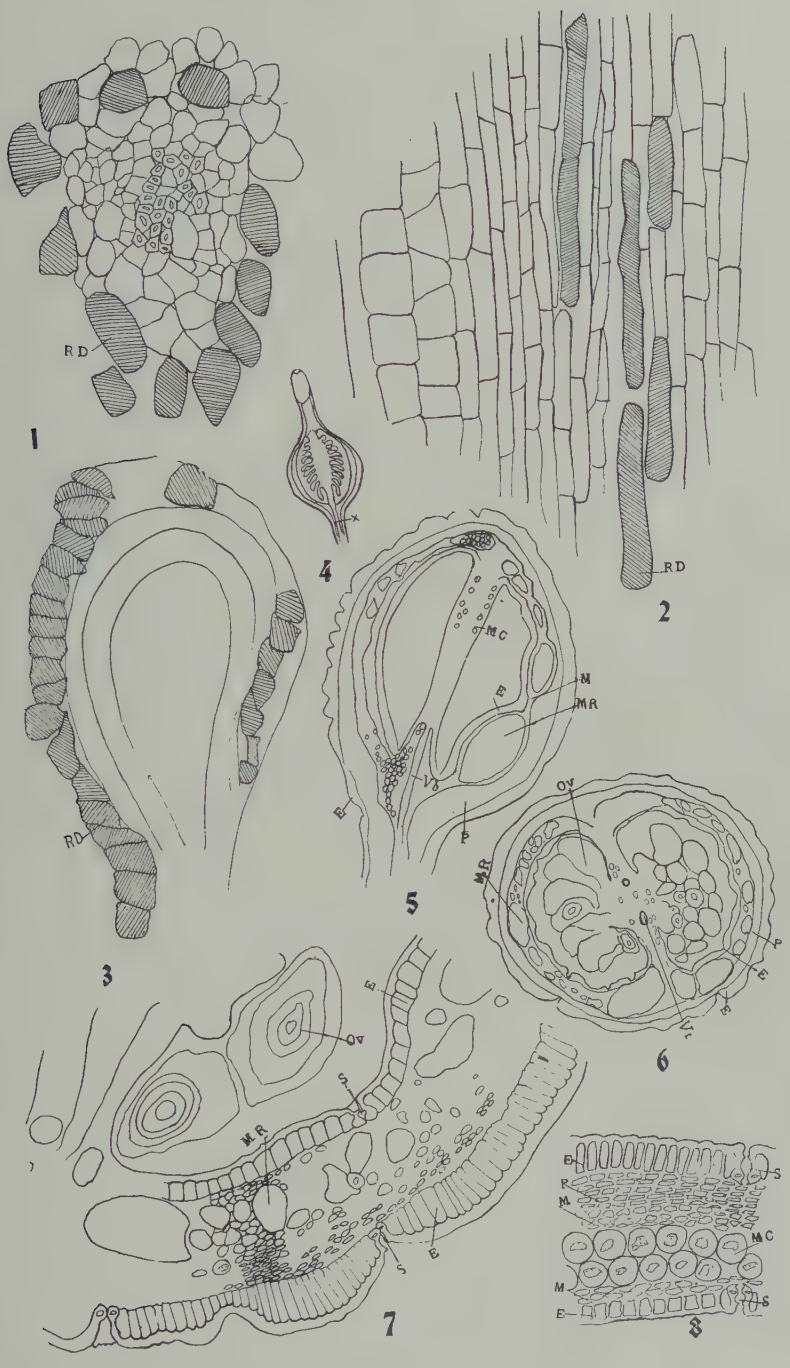
FIG. 4. Section of ovary. *X*, position of structures shown in figs. 1 and 2. Longi-section, × 5.

FIG. 5. Section showing position of mucilage reservoirs and other tissues in ovary. *MR*, mucilage reservoirs; *MC*, mucilage cells; *E*, epidermis; *p*, palisade tissue; *M*, mesophyll; *vb*, vascular bundle. Longi-section, × 55.

FIG. 6. Ovary. Reference letters same as (5). Cross, × 55.

FIG. 7. Portions of (6) more in detail. *OV*, ovule; *S*, stoma; for the other letters, see (5). Cross, × 283.

FIG. 8. Diagrammatic representation of regions in wall of ovary. Reference figures as above. Cross section enlarged.



The University of Chicago Library

PLATE XXV.

FIG. 1. Portion of ovary wall in detail. *OE*, outer epidermis; *M*, mesophyll; *Mr*, mucilage reservoirs; *IE*, inner epidermis; *IS*, inner stoma; *VB*, vascular bundles. Cross, × 283.

FIG. 2. Stoma from inner epidermis of ovary wall. Cross, × 283.

FIG. 3. Outline of portion of ovary wall, showing frequency of inner stomata, *S*. Cross, enlarged.

FIG. 4. Outer stoma, enlarged. Cross, × 283.

FIG. 5. Inflorescence, showing fruit. × 1.

FIG. 6. Single flower stalk. Sepals and petals dropped. Stamen *L* longer than stamen *S*. × 5.

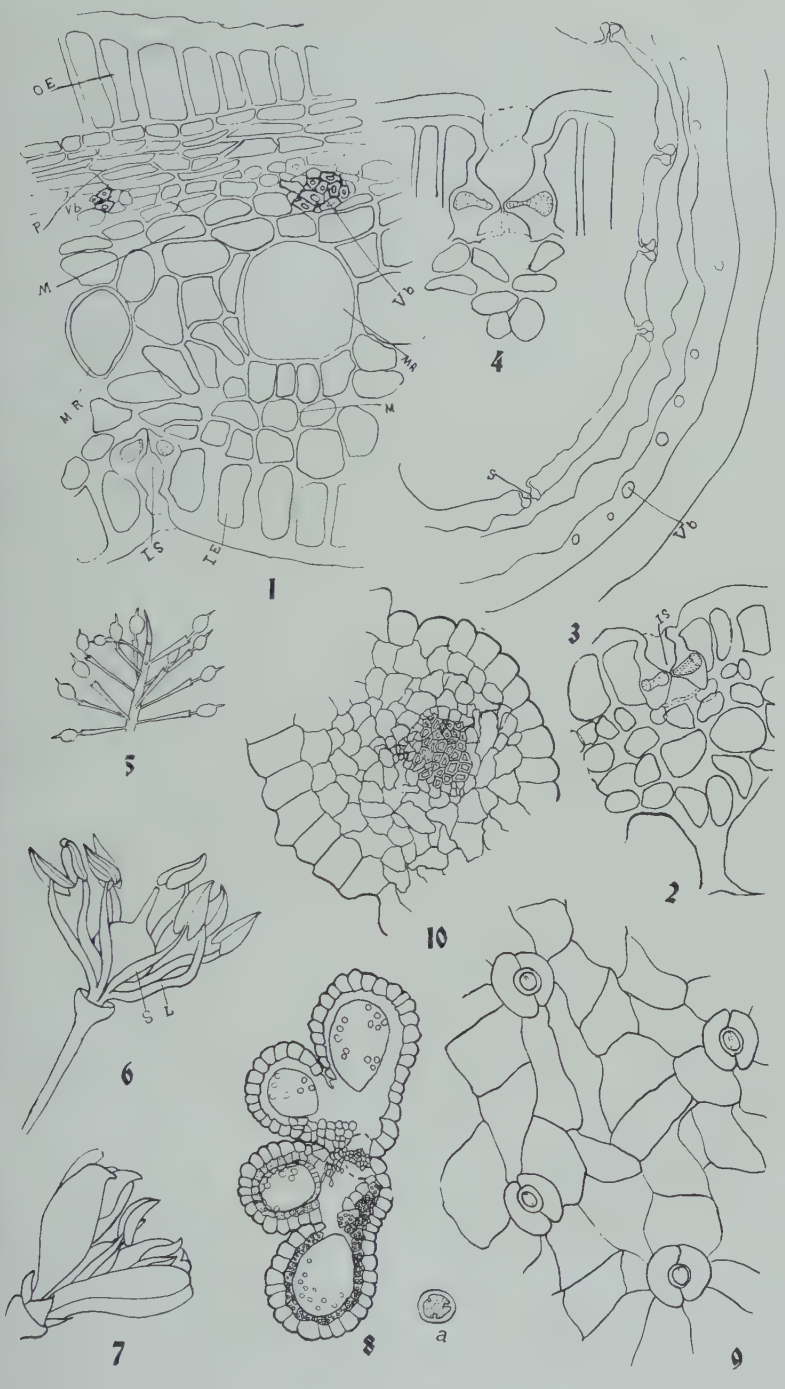
FIG. 7. Single flower. × 5.

FIG. 8. Section of anther, showing number of locules and thin-walled epidermis. Cross, × 283.

FIG. 8*a*. Pollen grain. × 636.

FIG. 9. Sunken stomata on outer epidermis of petals. × 283.

FIG. 10. Portion of petal, showing thin-walled epidermis. Cross, × 283.



The University of Chicago Library

PLATE XXVI.

FIG. 1.—Cross section through ovipositor, about midway: A. *cmgd*, cement gland duct; *ovid*, oviduct; *uv*, upper valve; *lv*, lower valve; *tg*, tongue and groove; *spg*, subgenital plate. B. Diagram showing position of ovipositor relative to plates.

FIG. 2.—Sport anal (?) vein of adult: *A*, anal vein; *C*, costa; *sv*, sport anal (?) vein.

FIG. 3.—Diagram of tracheation of nymphal wing pad of *P. celtidis-gemma* fore wing: *C*, costa; *Sc*, subcosta; *R*, radius; *M*, media; *Cu*, cubitus; *af*, anal fold; *A*, anal vein.

FIG. 4.—Diagram of tracheation of wing of recently emerged adult of *P. celtidis-mammæ*, fore wing.

FIG. 5.—Longitudinal-vertical section through wax glands: A. *wg*, wax glands; *n*, nucleus; *cu*, cuticula; *sh*, sense organs; *wgd*, wax gland ducts; *fb*, fat body. B. *wgo*, openings of wax glands, dorsal aspect.

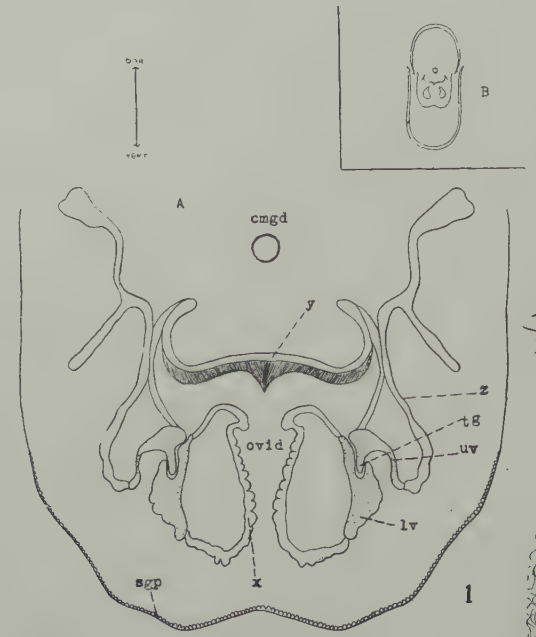
FIG. 6.—Tip of mandible.

FIG. 7.—Tip of maxilla.

FIG. 8.—Base of mandible: *te*, tendon.

FIG. 9.—Base of maxilla.

The University of Chicago Library



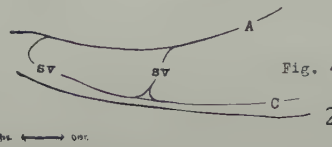


Fig. 41.

Fig. 39.

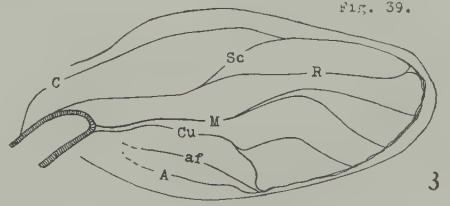
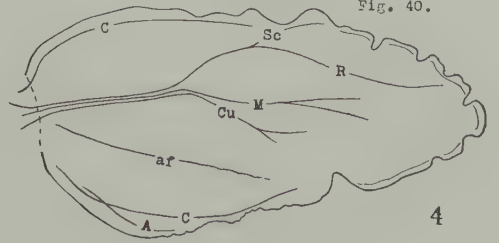


Fig. 40.



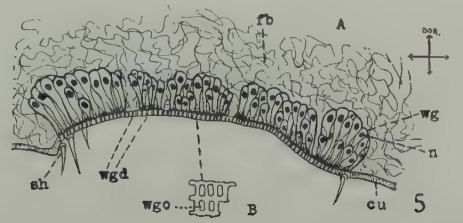


Fig. 25. x5000.

Fig. 26. x5000

Fig. 27. x6

Fig. 28. x65

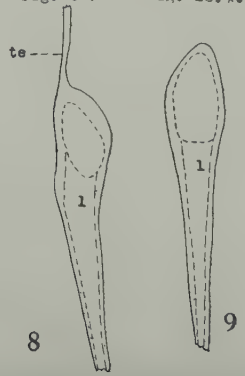


PLATE XXVII.

FIG. 1.—Lateral aspect of prothorax and mesothorax, diagrammatic: *pn*, pronotum; *es 1*, proepisternum; *es 1*, proepimeron; *pstr*, prosternum; *pcox*, procoxa; *sp*, spiracle; *dor*, dorsulum; *mm*, mesonotum; *scu*, scutellum; *artep*, articulatory epidemes; *bp*, base of primary; *em 2*, mesoepimeron; *es 2*, mesoepisternum; *mstr*, mesosternum; *end*, portion of endoskeleton.

FIG. 2.—Caudal aspect of mesothorax, diagrammatic: *ter*, tergum; *str*, mesosternum; *phr*, phragma; *apoph*, apophyse; *c*, canal; *apod*, apodeme; *es 2*, mesoepisternum; *em 2*, mesoepimeron; *end*, portion of endoskeleton corresponding to *end* in fig. 1, plate XXVII.

FIG. 3.—Sclerites forming tergum of thorax: A. *pn*, pronotum of prothorax; *dor*, dorsulum of mesothorax; *mm*, mesonotum of mesothorax; *scu*, scutellum of mesothorax; *mett*, metathorax. B. *median*, longitudinal section through tergum.

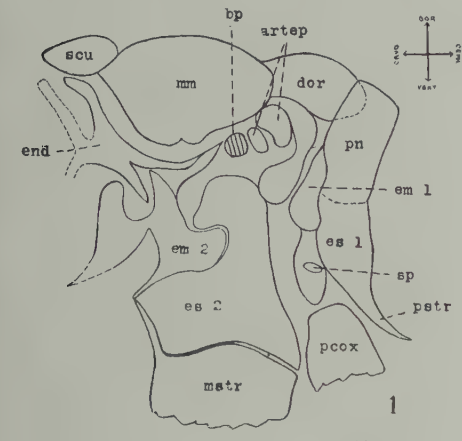
FIG. 4.—Chitinized process holding labium to thorax (cephalic aspect): A. *a*, lateral arm of process; *b*, yoke-like piece connecting lateral arms, caudad and dorsad of labium. B, tip of a lateral arm.

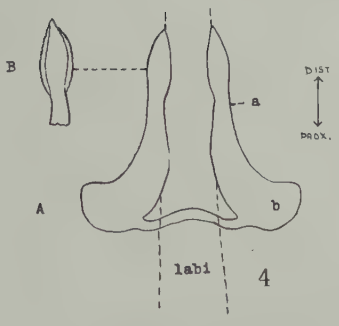
FIG. 5.—Ventral aspect of metathorax, diagrammatic: *str*, metasternum; *cox*, coxa; *em 3*, metaepimeron; *mer*, meracanthus; *troc*, trochanter; *mf*, ventral edge of metafurca.

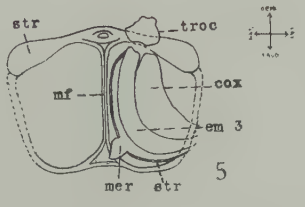
FIG. 6.—Venation of adult of *P. celtidis-mammæ*, fore wing: *c*, costa; *Sc + R*, subcostal plus radius; *s*, stigma; *Sc*, subcosta; *R*, radius; *M 1 2*, media; *M 3 4*, media; *Cu 1*, cubitus; *Cu 2*, cubitus; *af*, anal fold or "claval suture"; *cl*, clavus; *A*, anal vein; *Pc*, petiolus cubite.

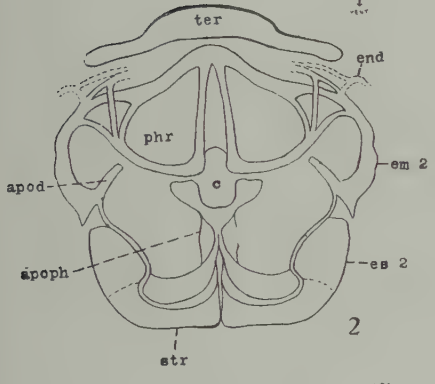
FIG. 7.—Venation of adult of *P. celtidis-mammæ*, hind wing.

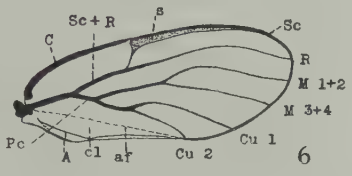
FIG. 8.—Ventral aspect of subgenital plate of female: *b*, base of plate; *a*, apex of plate; *sh*, sensory hairs.

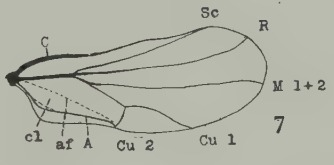


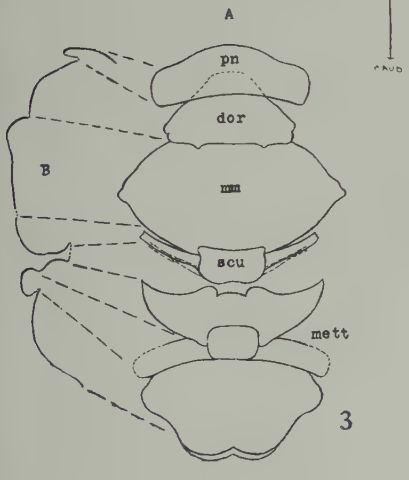


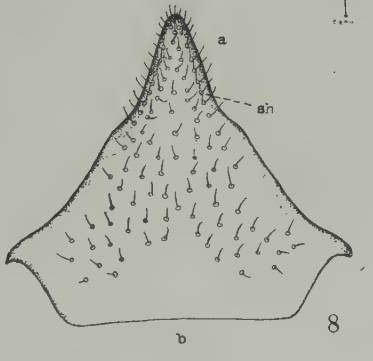












The University of Chicago Library

PLATE XXVIII.

FIG. 1.—Caudal aspect of head: *ep*, epicranium; *e*, compound eye; *fo*, front ocellus; *g*, gena; *fc*, frontal cone; *a*, antennal segments; *y*, projection from gena; *x*, portion of membrane forming fold around labium between procoxæ.

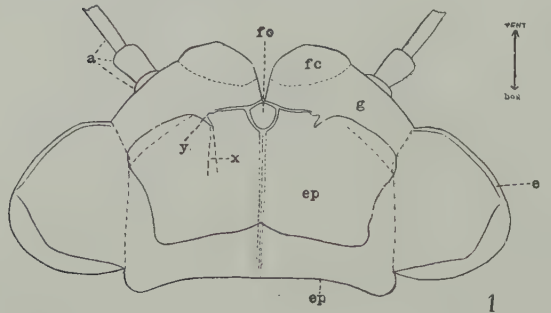
FIG. 2.—Longitudinal section of front ocellus: *cu*, cuticula; *hyp*, hypodermis; *l*, lens; *ip*, iris pigment; *v*, vitreous body; *r*, retinal cells; *n*, nerve.

FIG. 3.—Antenna.

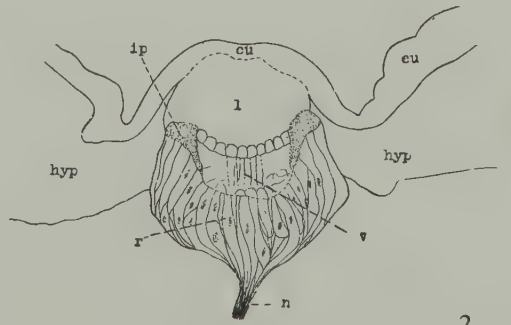
FIG. 4.—Cephalic aspect of head: *ep*, epicranium; *e*, compound eye; *o*, ocellus; *fo*, front ocellus; *g*, gena; *fc*, frontal cone; *a*, antennal segments; *as*, antennal socket.

FIG. 5.—Ventral aspect of head: *ep*, epicranium; *e*, compound eye; *fo*, front ocellus; *g*, gena; *fc*, frontal cone; *as*, antennal socket; *p*, projection from edge of antennal socket; *y*, projection from gena; *f*, frons; *lp*, ligamentary process of frons.

FIG. 6.—Articulation between third and fourth antennal segments: *a*, third segment; *b*, fourth segment; *cor*, corrugations; *sh*, sensory hairs.

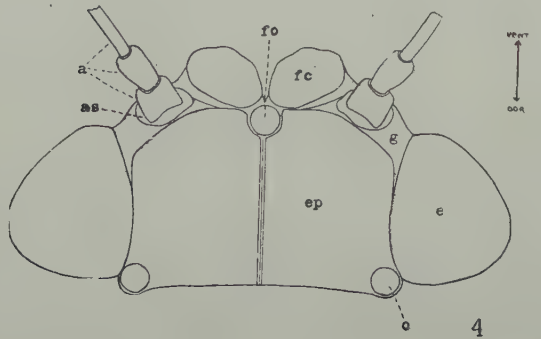


1

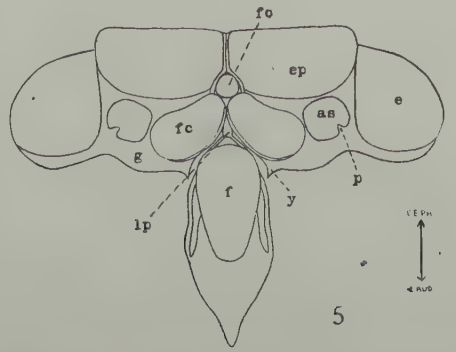


2

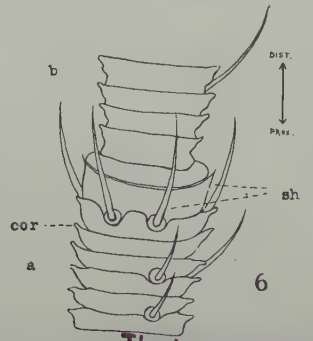
3



4



5



6

The University of Chicago Library

PLATE XXIX.

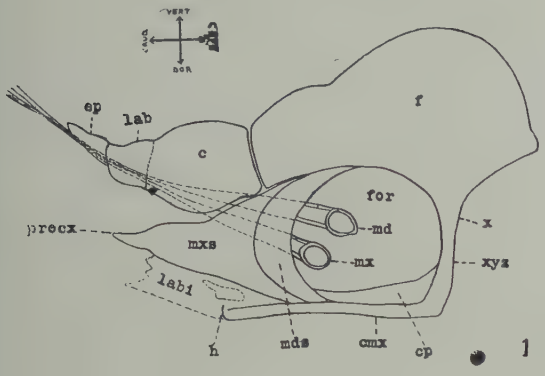
FIG. 1.—Lateral aspect of mouth parts, labium excepted: *f*, frons; *c*, clypeus; *lab*, labrum; *ep*, epipharynx; *md*, mandible; *mx*, maxilla; *mds*, mandibular sclerite; *mxs*, maxillary sclerite; *cmx*, chitinized plate for muscular attachment; *cp*, hypopharyngeal lamella; *procx*, maxillary process; *labi*, labium (base); *h*, hypopharynx; *for*, foramen.

FIG. 2.—Lateral aspect of mouth parts (diagrammatic): *f*, frons; *ep*, epipharynx; *s*, setæ; *labi 1*, *labi 2*, *labi 3*, three segments of labium; *mestr*, mesosternum; *p*, process of thorax for holding labium; *m*, membrane forming fold between procoxæ for labium.

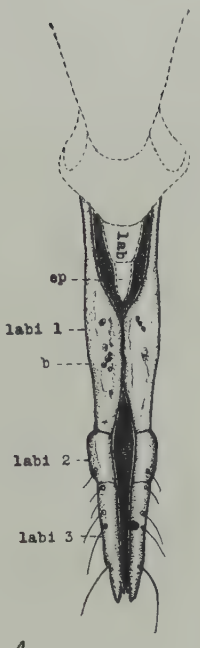
FIG. 3.—Ventral aspect of mouth parts, labium excepted: *f*, frons, *c*, clypeus; *lab*, labrum; *ep*, epipharynx; *md*, mandible; *ms*, maxillæ; *cmx*, chitinized plate for muscular attachment; *cp*, hypopharyngeal lamella; *mds*, mandibular sclerite; *mxs*, maxillary sclerite; *procx*, maxillary process.

FIG. 4.—Ventral aspect of labium: *f*, frons; *c*, clypeus; *lab*, labrum; *ep*, epipharynx; *labi 1*, *labi 2*, *labi 3*, three segments of labium; *b*, point where bend occurs.

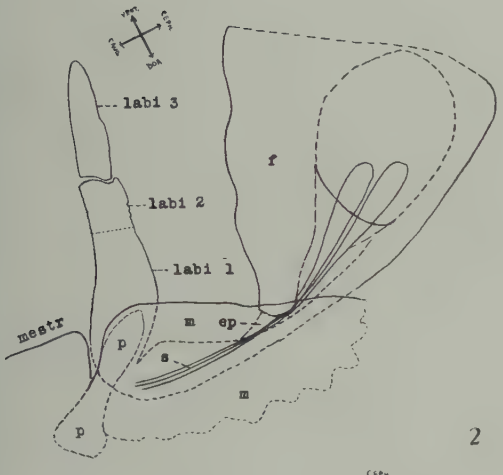
FIG. 5.—Dorsal aspect of mouth parts, labium excepted: *f*, frons; *lab*, labrum; *ep*, epipharynx; *md*, mandible; *mx*, maxillæ; *cmx*, chitinized plate for muscular attachment; *cp*, hypopharyngeal lamella; *procx*, maxillary process; *h*, hypopharynx; *t*, tentorium; *z*, proximal edge of frons; *p*, pharynx.



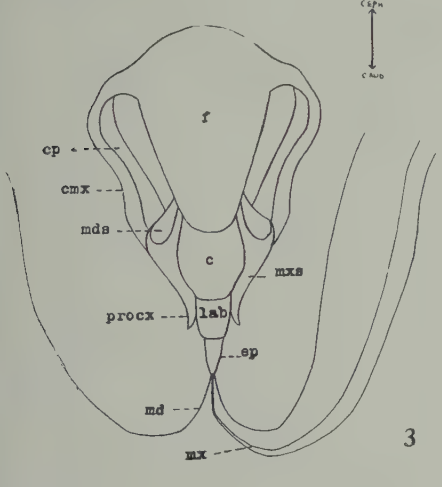
1



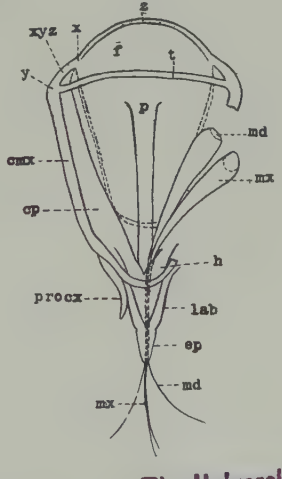
4



2



3



The University of Chicago Library

PLATE XXX.

FIGS. 1, 2 and 3.—Lateral, dorsal and ventral aspects of ovipositor, diagrammatic: *uv*, upper valves; *lv*, lower valves; *vs*, upper and lower valves (fig. 2); *buv*, base or support for *uv*; *blv*, base or support for *lv*; *sh*, sheath; *v*, valve closing oviduct; *procv*, process of rod for closing *v*; *sc*, laterally diverging pairs of sclerites cephalad of sheath (fig. 1); *sc 1*, proximal pair of sclerites; *sc 2*, distal pair of sclerites; *stp*, sting-palpi; *mr*, median rod; *lr*, lateral tendenous rod flattening out into lightly chitinized lateral plates, *lpt*.

FIG. 4.—Diagram showing position of ovipositor: *spp*, supra-anal plate; *a*, opening of anus; *sgp*, subgenital plate; *v*, valves of ovipositor; *sh*, sheath of ovipositor tip.

FIG. 5.—Lateral aspect of metafurca.

FIG. 6.—Caudal aspect of supra-anal plate: *spp*, supra-anal plate; *sppfl*, inner edges or flaps of supra-anal plate; *x*, distal portion of plate; *a*, anal opening; *lp*, lateral plate; *co*, base of copulatory organ; *l*, loop below copulatory organ.

FIG. 7.—Lateral aspect of supra-anal plate and copulatory organ: *spp*, supra-anal plate; *sppfl*, inner edges or flaps of supra-anal plate; *x*, distal portion of plate; *a*, anal opening; *lp*, lateral plate; *co*, copulatory organ; *g*, geniculation; *c*, club; *p*, penis; *l*, loop below copulatory organ; *y*, slit in base of copulatory organ.

FIG. 8.—Cephalic aspect of metathorax, diagrammatic: *str*, metasternum; *mf*, metafurca; *la*, lateral projection of endoskeleton; *mett*, metatergum.

FIG. 9.—Section through fore wing: *wm*, wing membrane; *b*, pigmented disc; *a*, unpigmented disc; *c*, cuticular processes on ventral surface of wing.

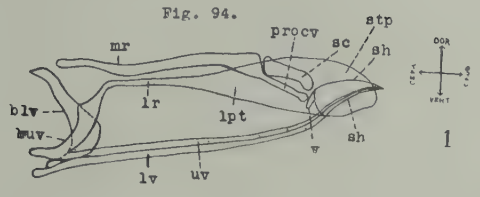


Fig. 94.

1

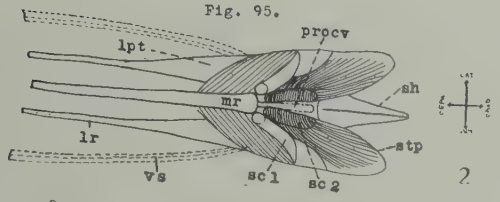


Fig. 95.

2

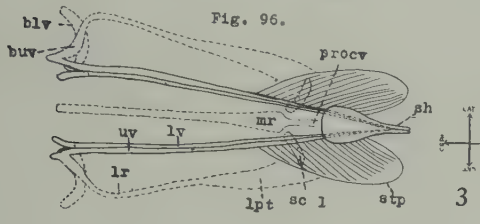
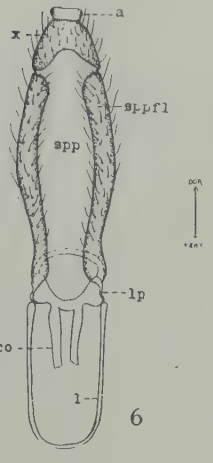
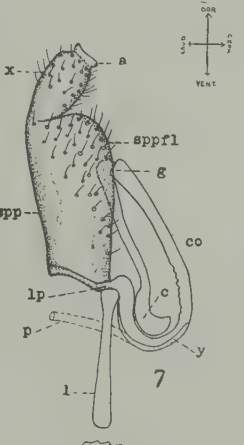


Fig. 96.

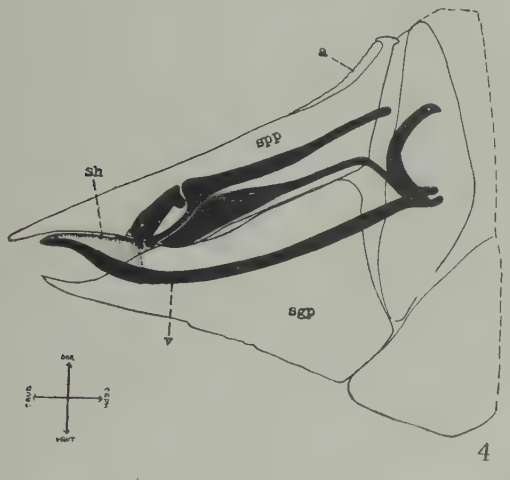
3



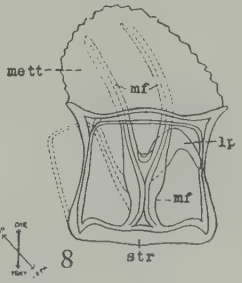
6



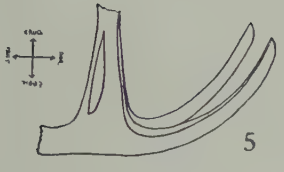
7



4



8



5

9

The University of Chicago Library

PLATE XXXI.

FIG. 1.—Cross section through procoxæ and mouth parts: *cox*, coxa; *c*, clypeus; *p* and *pc*, parts of pharyngeal canal; *mds*, mandibular sclerite; *mxs*, maxillary sclerite; *s*, setæ; *cp*, hypopharyngeal lamella; *m*, membrane forming fold between procoxæ to hold labium.

FIG. 2.—Lateral aspect of tip of labium: *t*, lateral tongue-like processes; *sh*, sense organs.

FIG. 3.—Cephalic aspect of tip of labium: *t*, lateral tongue-like processes; *sh*, sense organs; *sl*, slit of labium.

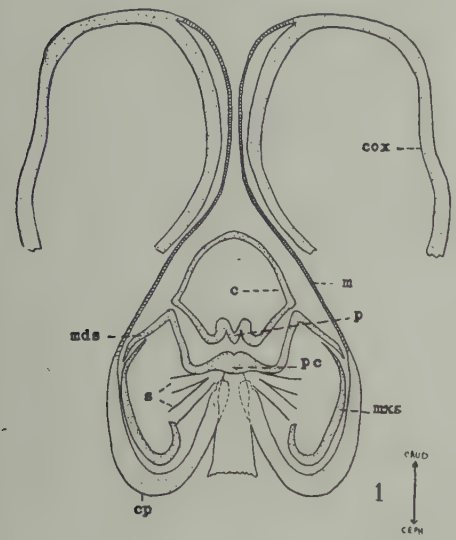
FIG. 4.—Base of supra-anal plate of female showing wax glands: *a*, anal opening; *wgo*, openings of ducts of wax glands; *sh*, sense organs; *x*, chitinized portion of plate; *y*, slightly chitinized, translucent portion of plate.

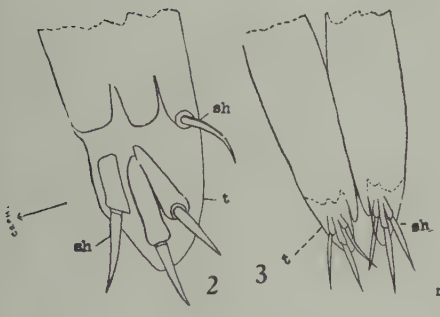
FIG. 5.—Cross section of *labi 1*: *md*, mandible; *mx*, maxilla; *m*, longitudinal muscles; *sl*, slit of labium; *l*, lumen in mandible.

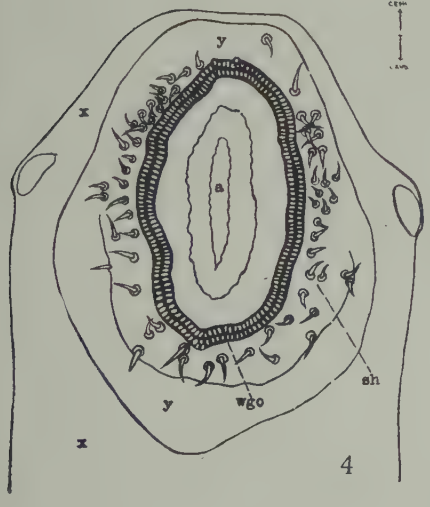
FIG. 6.—Cross section of ovipositor through base of sheath: *spp*, supra-anal plate; *sgp*, subgenital plate; *ovid*, oviduct; *sh*, sheath; *stp*, sting-palpi.

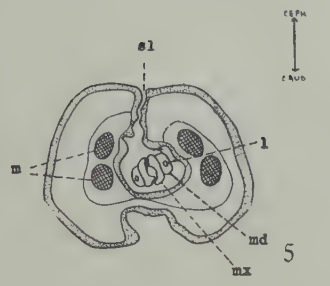
FIG. 7.—Lateral aspect of metathorax, part of metasternum, epimeron, meracanthus, coxa, etc., removed, diagrammatic: *mett*, metatergum; *mf*, metafurca; *bs*, region of base of secondary; *es 3*, region of metaepisternum; *str*, part of metasternum; *end*, a rod connected to metafurca; *x*, point of articulation of *em 3*.

FIG. 8.—Lateral aspect of metathorax, part of metasternum, episternum and metafurca removed, diagrammatic: *mett*, metatergum; *mf*, metafurca; *str*, part of metasternum; *mer*, meracanthus; *em 3*, metaepimeron; *cox*, coxa; *scl*, an accessory sclerite; *x* and *y*, articulation of *em 3*; *troc*, trochanter; *fem*, femur.









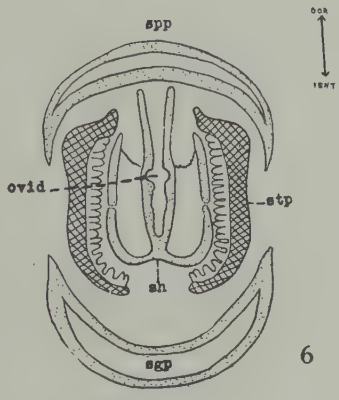
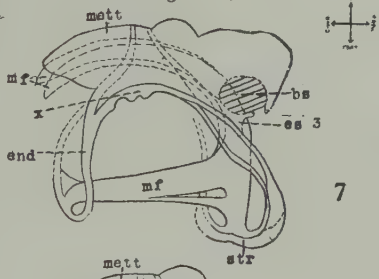


Fig. 37. x 71



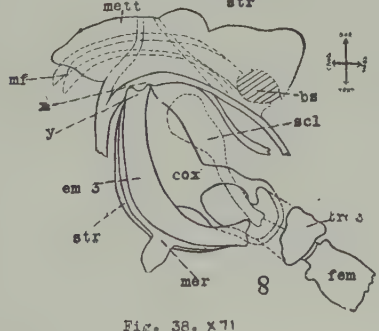


Fig. 38. x 71

The University of Chicago Library

PLATE XXXII.

FIG. 1.—Frons and mouth parts, labium excepted, removed from head. (Photo.)

FIGS. 2, 3 and 4.—Wings of male. (Photos.)

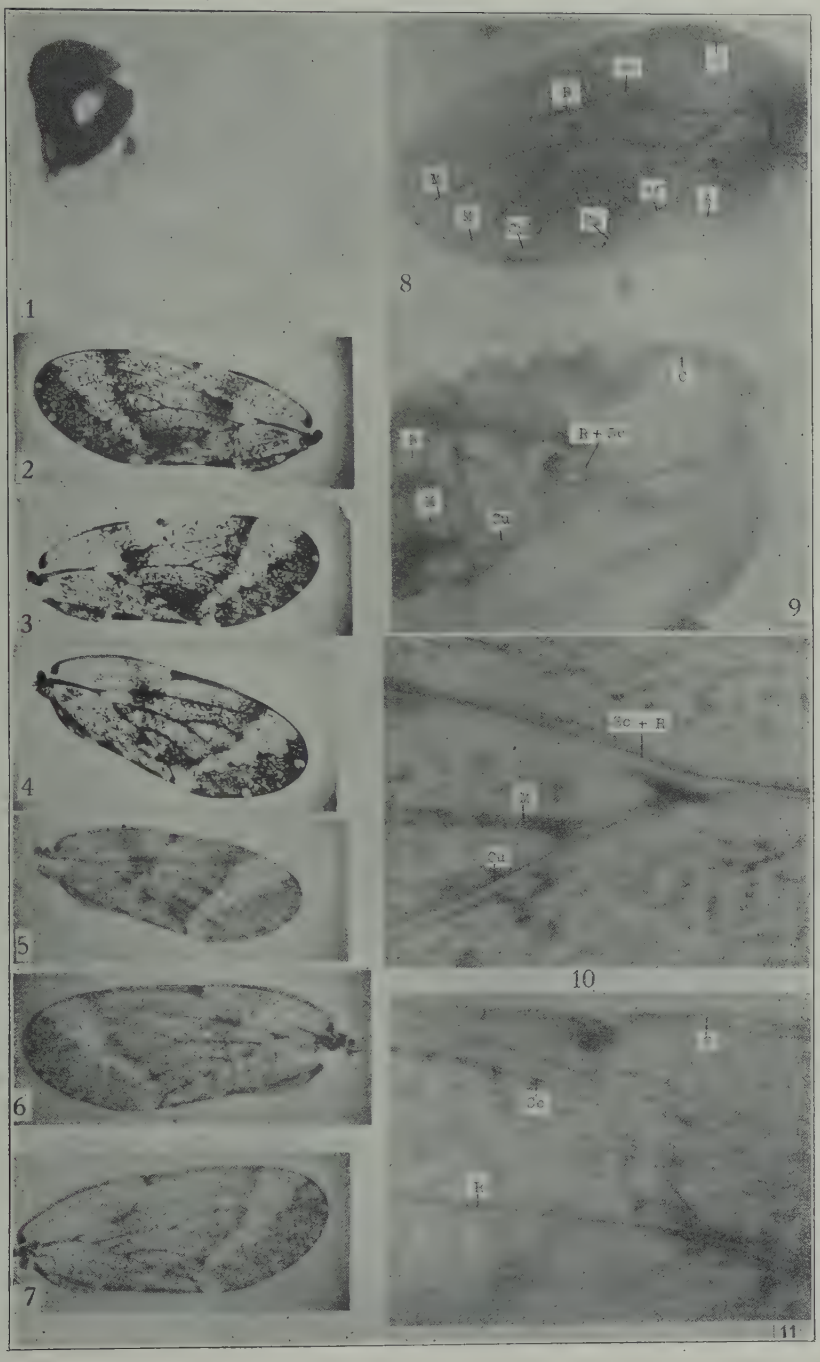
FIGS. 5, 6 and 7.—Wings of female. (Photos.)

FIG. 8.—Tracheation of nymphal wing pad of *P. celtidis-gemma*, fore wing. (Photo.) *C*, costa; *Sc*, subcosta; *R*, radius; *M*, *M*, media; *Cu*, *Cu*, cubitus.

FIG. 9.—Tracheation of wing of recently emerged adult of *P. celtidis-mammæ*, fore wing. (Photo.) *C*, costa; *Sc* + *R*, radius plus subcosta; *R*, radius; *M*, media; *Cu*, cubitus.

FIG. 10.—Branching of media and cubitus from radius plus subcosta in fore wing of recently emerged *P. celtidis-mammæ*: *Sc* + *R*, radius plus subcosta; *M*, media; *Cu*, cubitus.

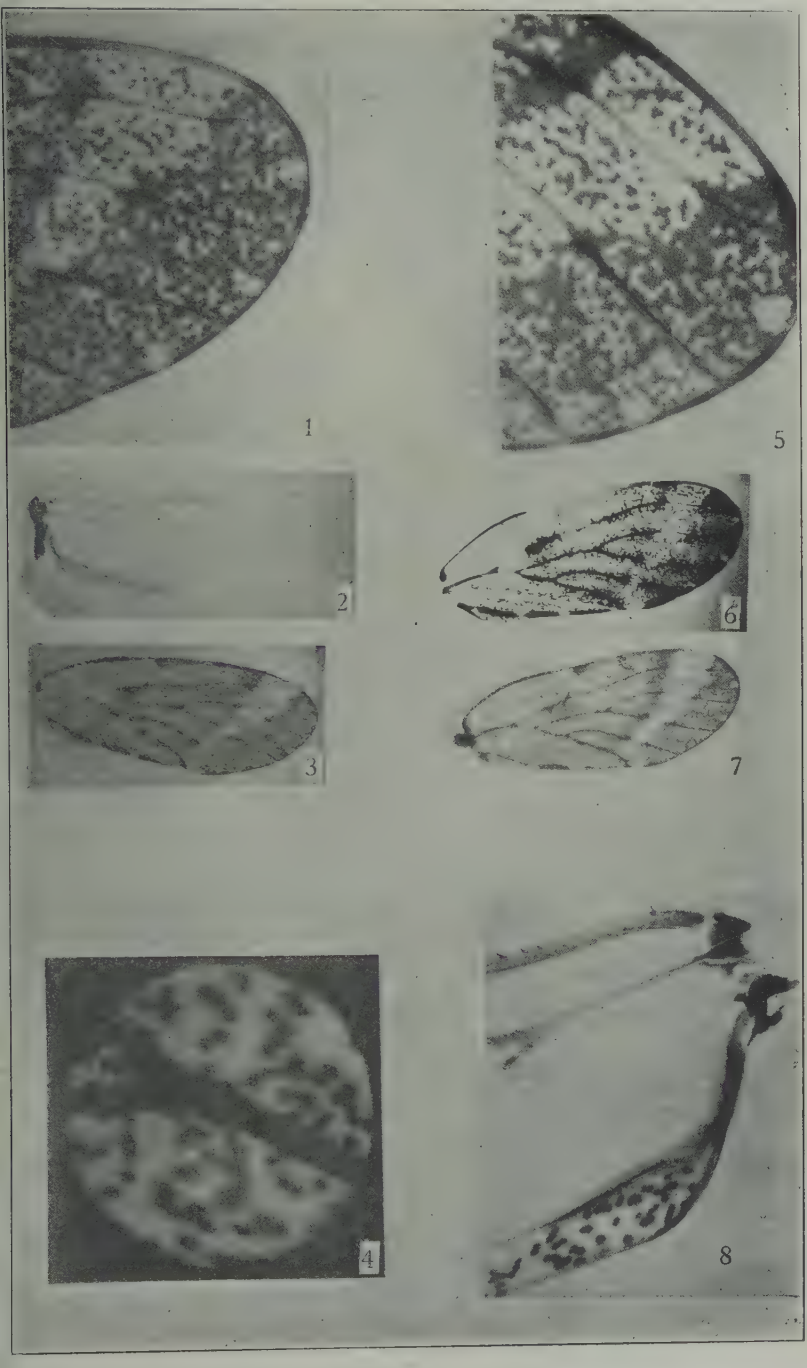
FIG. 11.—Branching of subcosta and radius in fore wing of recently emerged *P. celtidis-mammæ*: *Sc*, subcosta; *R*, radius; *C*, costa.



The University of Chicago Library

PLATE XXXIII.

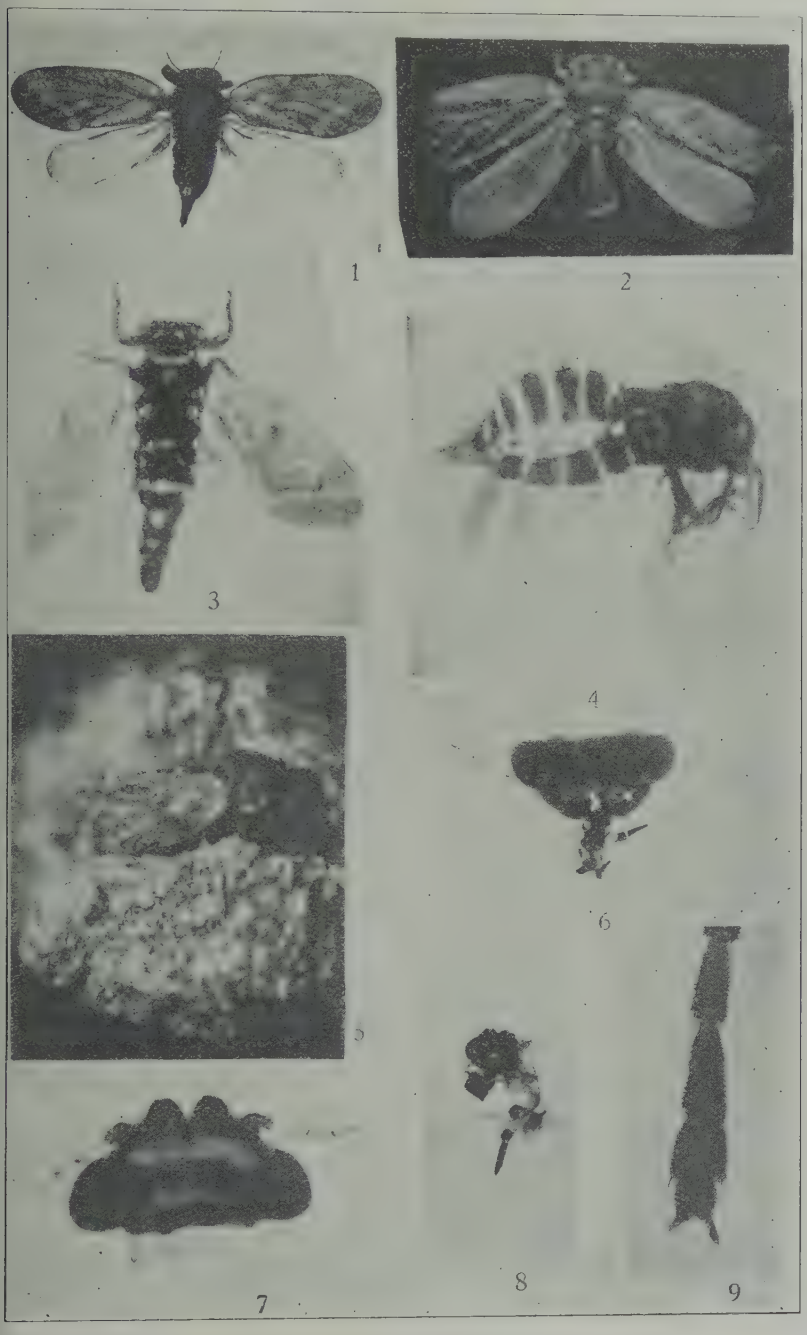
FIG. 1.—Apex of wing of male, showing pattern. (Photo.)
FIG. 2.—Hind wing. (Photo.)
FIGS. 3 and 6.—Wings of females. (Photos.)
FIG. 4.—Highly magnified portion of pattern. (Photo.)
FIG. 5.—Apex of wing of female, showing pattern. (Photo.)
FIG. 7.—Wing of male. (Photo.)
FIG. 8.—Base of hind wing, showing pattern and hairs on costa. (Photo.)



The University of Chicago Library

PLATE XXXIV.

FIG. 1.— ——— Dorsal aspect of male. (Photo.)
FIG. 2.— ——— Dorsal aspect of male. (Photo.)
FIG. 3.—Ventral aspect of male. (Photo.)
FIG. 4.—Lateral aspect of female. (Photo.)
FIG. 5.—*Pachypsylla* on bark of hackberry, showing protective markings. (Photo.)
FIG. 6.—Head, antennæ, and mouth parts. (Photo.)
FIG. 7.—Photograph of head and antennæ.
FIG. 8.—Lateral aspect of mouth parts, removed from head. (Photo.)
FIG. 9.—Last four joints of antenna.



The University of Chicago Library

PLATE XXXV.

FIG. 1.—Metathoracic tarsi. (Photo.)

FIG. 2.—Prothoracic tarsi. (Photo.)

FIG. 3.—Mesothoracic tarsi. (Photo.)

FIG. 4.—Dorsal aspect of supra-anal plate of female. (Photo.)

FIG. 5.—Mesothoracic leg. (Photo.)

FIG. 6.—Prothoracic leg. (Photo.)

FIG. 7.—Lateral aspect of copulatory organ. (Photo.)

FIG. 8.—Metathoracic leg. (Photo.) *scl*, accessory sclerite.

FIG. 9.—Lateral aspect of ovipositor. (Photo.)

FIG. 10.—Lateral aspect of male genitalia. (Photo.) *spp*, supra-anal plate; *sgp*, subgenital plate; *co*, copulatory organ; *f*, forceps.

FIG. 11.—Mesothoracic legs with mesosternum. (Photo.) *apoph*, apophyse.

FIG. 12.—Prothoracic legs, pronotum, etc. (Photo.) *pn*, pronotum; *es 1*, proepisternum; *em 1*, proepimeron; *cox*, coxæ.

FIG. 13.—Lateral aspect of female abdomen. (Photo.)

FIG. 14.—Lateral aspect of male abdomen. (Photo.) (Figure inverted.)

FIG. 15.—Cephalic aspect of forceps. (Photo.)

The University of Chicago Library

PLATE XXXVI.

FIG. 1. Tangential section of *Populus alba* with pits in wall between medullary ray and phloëm parenchyma and between two parenchyma cells.

FIG. 2. Side view of obliquely placed end sieve plate from *Populus alba* and with pits between the sieve tubes and the other phloëm cells. Tangential section.

FIG. 3. A pit in a vertical wall between a medullary ray and the phloëm of *Populus alba.*

FIG. 4. Transverse or reticulate strengthening bands on the wall of a sieve tube in a root of *Populus deltoides.* Tangential section.

FIG. 5. Transverse bands on the wall of a sieve tube in the root of *Populus deltoides,* as seen in section.

FIG. 6. Transverse section in *Amorpha fruticosa,* showing the radially elongated medullary-ray cells and others similar to these sweeping around the narrow strip of phloëm and arranged to conduct food from these radially, especially to the cambium.

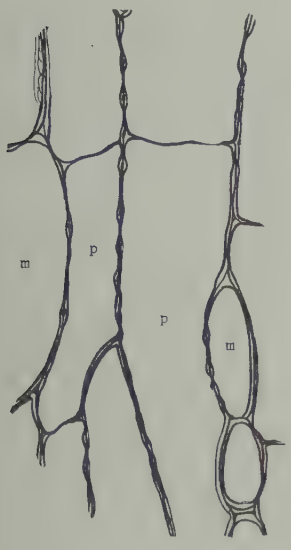
DESCRIPTION OF FIGURES.

Plates XXXVI and XXXVII.

Explanatory notes: Magnification is 600, except in figure 6, where it is 250 approximately.

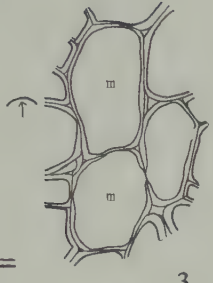
Lettering: st = sieve tube; m = medullary ray; p = parenchyma; camb = cambium; stch = starch; cr = crystal; pt = pit; n = nucleus.

Symbols: $\rightarrow$) and $\rightarrow$] = direction toward nearest point of circumference or in the epidermis.



1

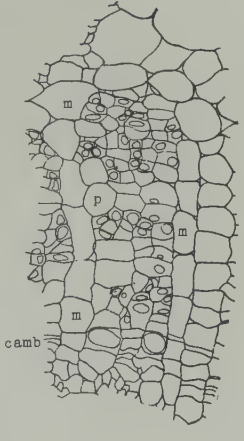
2



3

4

5



6

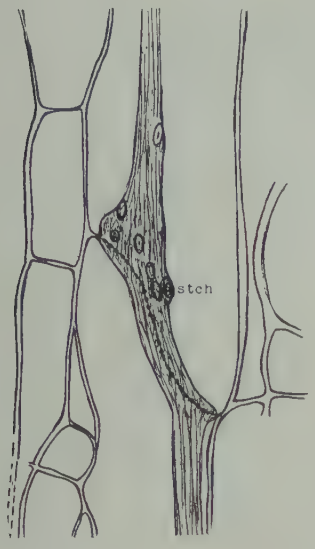
The University of Chicago Library

PLATE XXXVII.

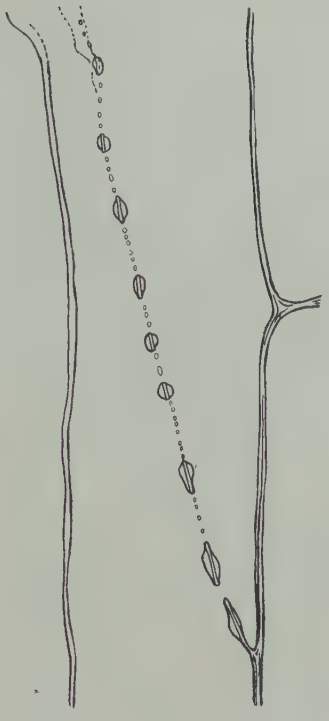
FIG. 7. Tangential section of *Populus alba*, showing the "beaded" end plate of a sieve tube and starch granules in the slime body.

FIG. 8. Tangential section in the root of *Populus deltoides*, showing one of the remarkable obliquely placed end plates of a sieve tube in cross section. The strengthening bands here appear as larger beads and the perforation of the wall as spaces between smaller beads. This long plate evidently gives more surface for the distribution of the pits and possibly better communication between the two cells of the sieve tube.

FIGS. 9 and 10 are from tangential sections of the root of *Populus deltoides*, and show the reticulated markings caused by the pitting and banding of the obliquely placed end plates in the sieve tubes. In figure 10 the sieve tube adjoins a medullary-ray cell.

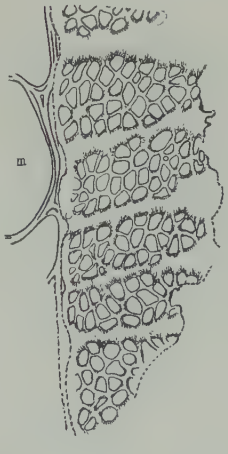


7



8

9



10

The University of Chicago Library

PLATE XXXVIII.

Townsendia exscapa.

FIG. 1. View from "Castle Rock Bluffs," Gove county, Kansas, showing the habitat of *Townsendia* in the foreground.

1

The University of Chicago Library

PLATE XL.

Townsendia exscapa.

FIG. 4. Cutinized epidermis of stem, cross section. *R*, outer tangential wall; *S*, inner tangential wall. × 650.

FIG. 5. Cork cells, cross section. × 650.

FIG. 6. Collenchyma cells, cross section. × 650.

FIG. 7. Collenchyma cells, longitudinal section. × 650.

FIG. 8. Short sclerenchyma cells, cross section. × 650.

FIG. 9. Short sclerenchyma cells, longitudinal section. × 650.

FIG. 10. Cortex cells, cross section. × 650.

FIG. 11. Cortex cells, longitudinal section. × 650.

FIG. 12. Pith cells, cross section. × 650.

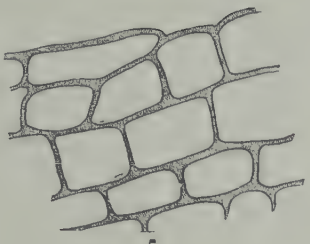
FIG. 13. Pith cells, longitudinal section. × 650.

FIG. 14. Small portion of xylem, cross section, showing: *a*, tracheids; *b*, wood parenchyma cells. × 650.

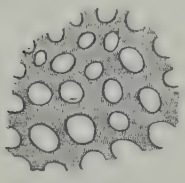
FIG. 15. Tracheids, as seen in a longitudinal section, when isolated from the wood parenchyma cells by means of chromic acid. × 650.

PLATE XL.

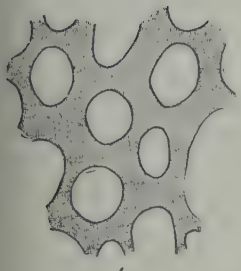
4



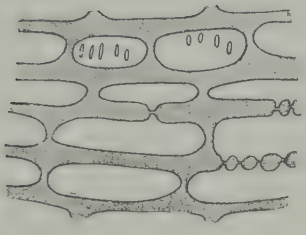
5



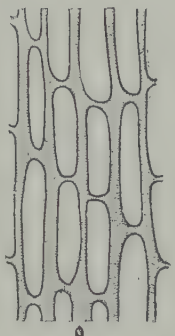
8



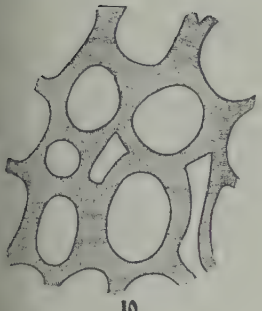
6



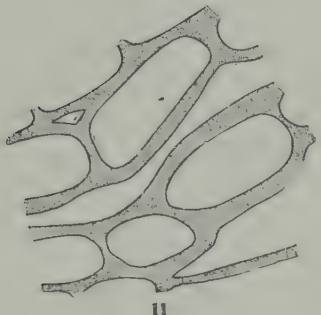
7



9

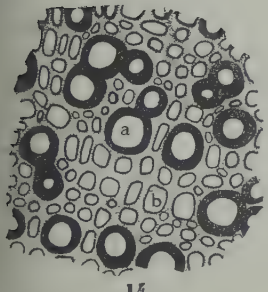


10

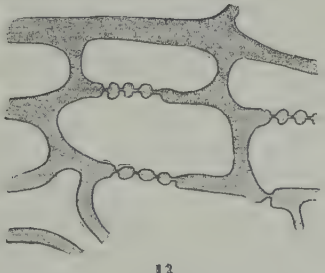


11

15



14



13

12

The University of Chicago Library

PLATE XLI.

Townsendia exscapa.

FIG. 16. Medullary-ray cells, cross section. × 650.

FIG. 17. Medullary-ray cells, longitudinal section. × 650.

FIG. 18. Phloëm cells, cross section. × 650.

FIG. 19. Phloëm cells, longitudinal section: *a*, cambiform cell; *b*, undivided mother cell of the sieve tubes. × 650.

FIG. 20. Cross section of root, showing the distribution of tracheids. × 115.

FIG. 21*a*. A bleached leaf, showing its method of venation. × 12½.

FIG. 21*b*. Midrib of leaf, cross section, showing: *a*, phloëm cells; *b*, tracheids; *c*, wood parenchyma cells. × 215.

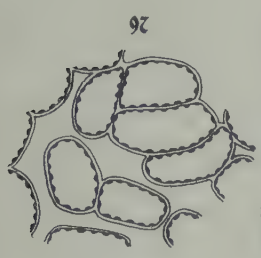
FIG. 22. Portion of a bleached leaf, showing the details of venation. × 115.

FIG. 23. Phloëm cells as seen in a longitudinal section of the midrib of a leaf: *a*, cambiform cell; *b*, undivided mother cell of the sieve tubes. × 650.

FIG. 24. Cutinized epidermis of leaf, cross section: *a*, cuticle; *b*, cutinized portion of wall. × 650.

FIG. 25. Palisade cells, surface view: *c*, intercellular spaces; *d*, palisade cell. × 650.

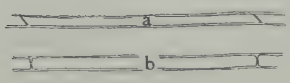
FIG. 26. Spongy parenchyma cells, surface view. × 650.



26

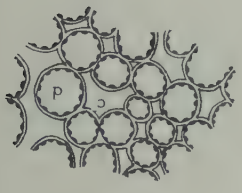
17

18

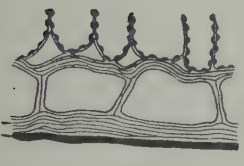


19

20

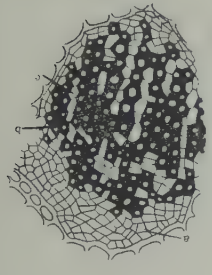


25

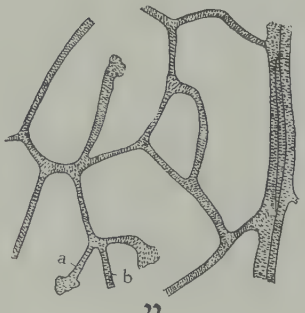


24

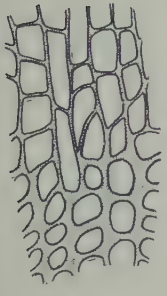
21 a



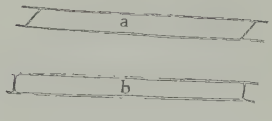
21 b



22



16



23

The University of Chicago Library

PLATE XLII.

Townsendia exscapa.

FIG. 27. Diagrammatic drawing showing the distribution of water-storage cells as seen in cross section of a leaf: *a*, veins; *b*, water-storage cells.

FIG. 28. Palisade cells bordering on water-storage cells: *A*, water-storage cells; *B*, palisade cells; *a*, chloroplasts found in water-storage cells. × 650.

FIG. 29. Palisade cells bordering on the veins: *A*, palisade cells; *B*, border parenchyma cells; *C*, tracheids. × 650.

FIG. 30. Palisade cells bordering on water-storage cells and storage tracheids: *A*, water-storage cells; *B*, chloroplasts found in water-storage cells; *C*, water-storage tracheids; *D*, palisade cells. × 650.

FIG. 31. Palisade cells bordering on water-storage cells, which in turn border on veins: *A*, water-storage cell; *B*, chloroplasts; *C*, tracheids; *D*, border parenchyma cells. × 650.

FIG. 32. Palisade cells bordering on spongy parenchyma cells: *A*, palisade cell; *B*, spongy parenchyma cell; *C*, intercellular spaces. × 650.

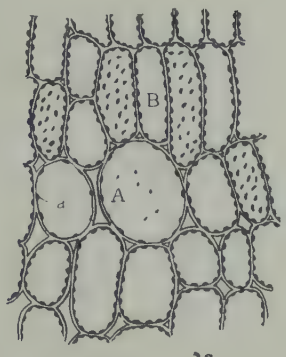
FIG. 33. Water-storage tracheids as they appear at the ultimate ends of the veins: *A*, veins; *B*, water-storage tracheids. × 650.

FIG. 34. Water-storage tracheids as they appear in other places in the leaf: *A*, ordinary tracheids; *B*, water-storage tracheids. × 650.

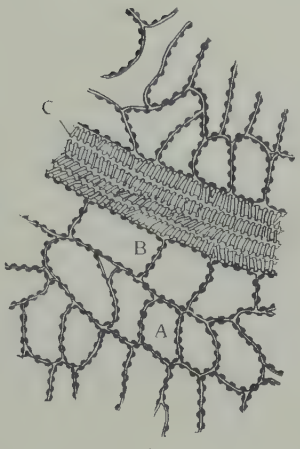
FIG. 35. Stomata, surface view. × 650.

FIG. 36. Stoma, as seen in cross section of the leaf. × 650.

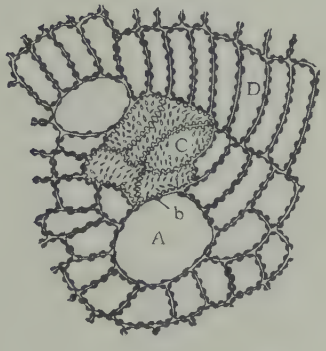
27



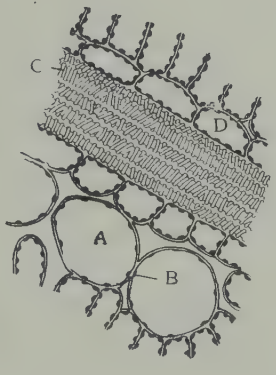
28



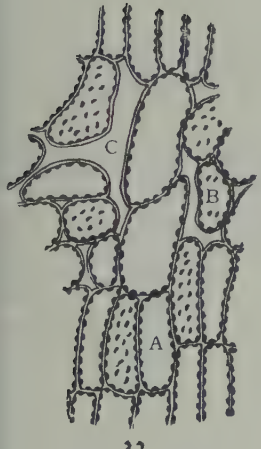
29



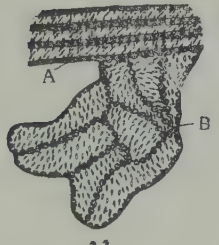
30



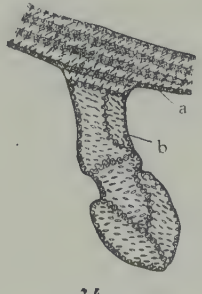
31



32



33



34

35

36

The University of Chicago Library

PLATE XLIII.

Lesquerella spathulata.

FIG. 37. Cutinized epidermis of stem, cross section: *S*, outer tangential wall; *T*, inner tangential wall. × 650.

FIG. 38*a*. Cutinized epidermis of stem, longitudinal section: *S*, outer tangential wall; *T*, inner tangential wall. × 650.

FIG. 38*b*. Cork cells as seen in cross section. × 650.

FIG. 39. Stone cells found in the borke, cross section. × 650.

FIG. 40. Collenchyma cells, cross section. × 650.

FIG. 41. Collenchyma cells, longitudinal section. × 650.

FIG. 42. Stone cells found in sclerenchyma tissue, cross section. × 650.

FIG. 43. Stone cells found in sclerenchyma tissue, longitudinal section. × 650.

FIG. 44. Bast fibers, longitudinal section. × 650.

FIG. 45. Bast fibers, cross section. × 650.

FIG. 46. Small portion of xylem, cross section: *A*, wood fibers; *B*, wood parenchyma cells; *C*, tracheal elements.

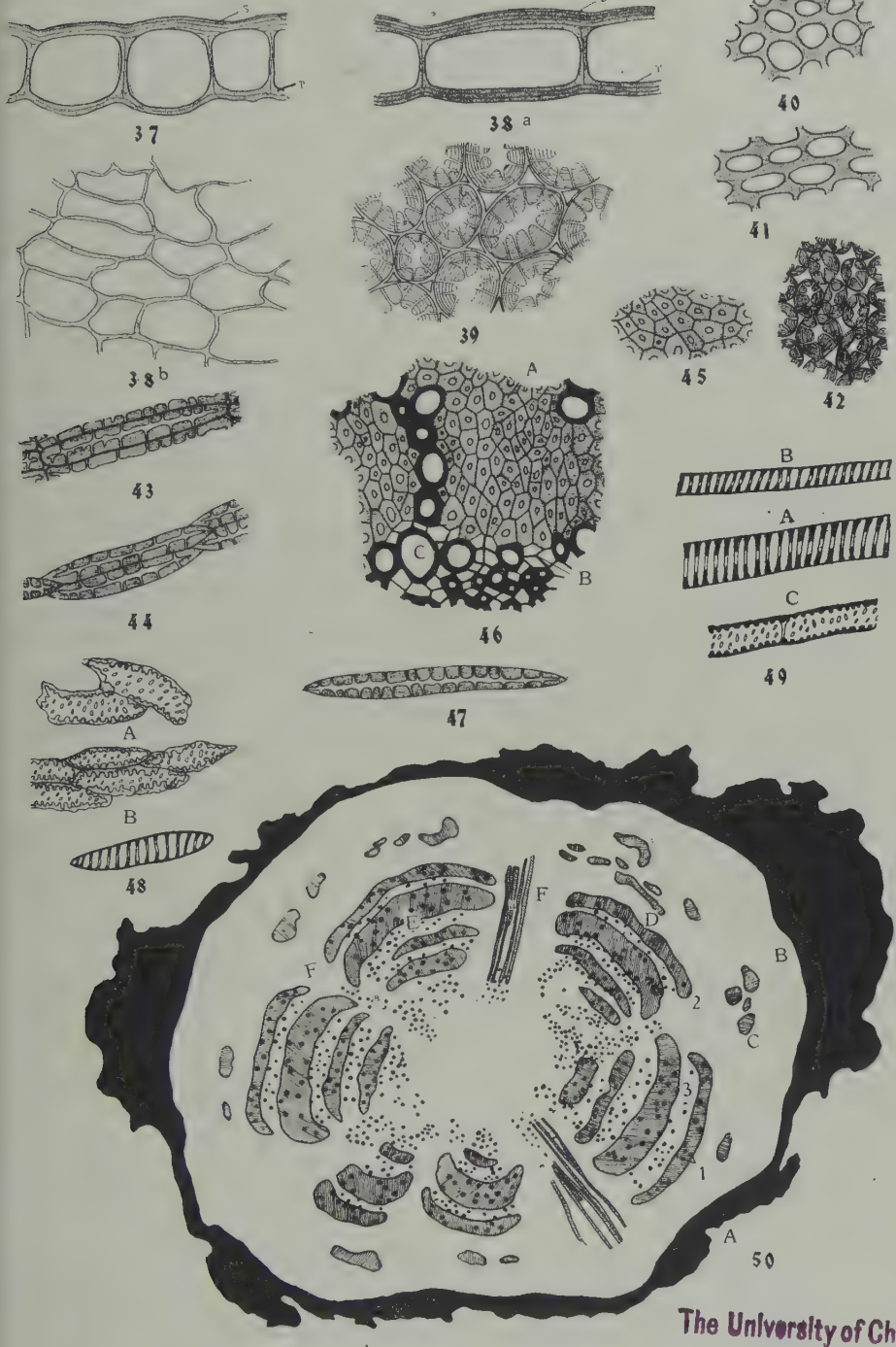
FIG. 47. Wood fiber, longitudinal section. × 650.

FIG. 48. Tracheal elements found in the stem at the nodes as seen in longitudinal section: *A*, scalariform type of tracheids; *B*, spiral type of tracheids. × 650.

FIG. 49. Tracheal elements found in the internodes of the stem, as seen in longitudinal section: *A*, spiral tracheal tubes found among the wood fibers; *B*, spiral tracheal tubes found among the wood parenchyma cells; *C*, scalariform tracheal tubes. × 650.

FIG. 50. Diagrammatic drawing of the cross section of the stem: *A*, borke; *B*, collenchyma; *C*, sclerenchyma; *D*, phloëm; *E*, xylem; 1, tracheal tissues; 2, wood fibers; 3, xylem parenchyma; *F*, medullary ray; *a*, leaf trace. × 87½.

PLATE XLIII.



The University of Chicago Library

PLATE XLIV.

Lesquerella spathulata.

FIG. 51*a*. Spiral tracheal tubes found in the leaf trace. × 650.

FIG. 51*b*. Small portion of the medullary ray, as seen in cross section. × 650.

FIG. 51*c*. Phloëm cells, as seen in cross section: *A*, intercellular spaces. × 650.

FIG. 52. Phloëm cells, as seen in longitudinal section: *A*, intercellular spaces. × 650.

FIG. 53. Thin-walled parenchyma cells of the cortex, cross section. × 650.

FIG. 54. Xylem parenchyma cells, as seen in longitudinal section. × 650.

FIG. 55. Wood fibers and tracheal tubes found in the outermost layer of xylem, cross section. × 650.

FIG. 56*a*. Segment of the cross section of the root, showing the constitution of the xylem: *A*, wood fibers; *B*, tracheal elements; *C*, wood parenchyma. × 53.

FIG. 56*b*. Tracheal elements found in the root: *A* and *B*, scalariform tracheal tubes; *C*, spiral tracheal tube. × 650.

FIG. 57. Tracheal tubes and wood parenchyma cells found in the layer of xylem (fig. 56*a*, *F*): *A*, tracheal tubes; *B*, wood parenchyma cells. × 650.

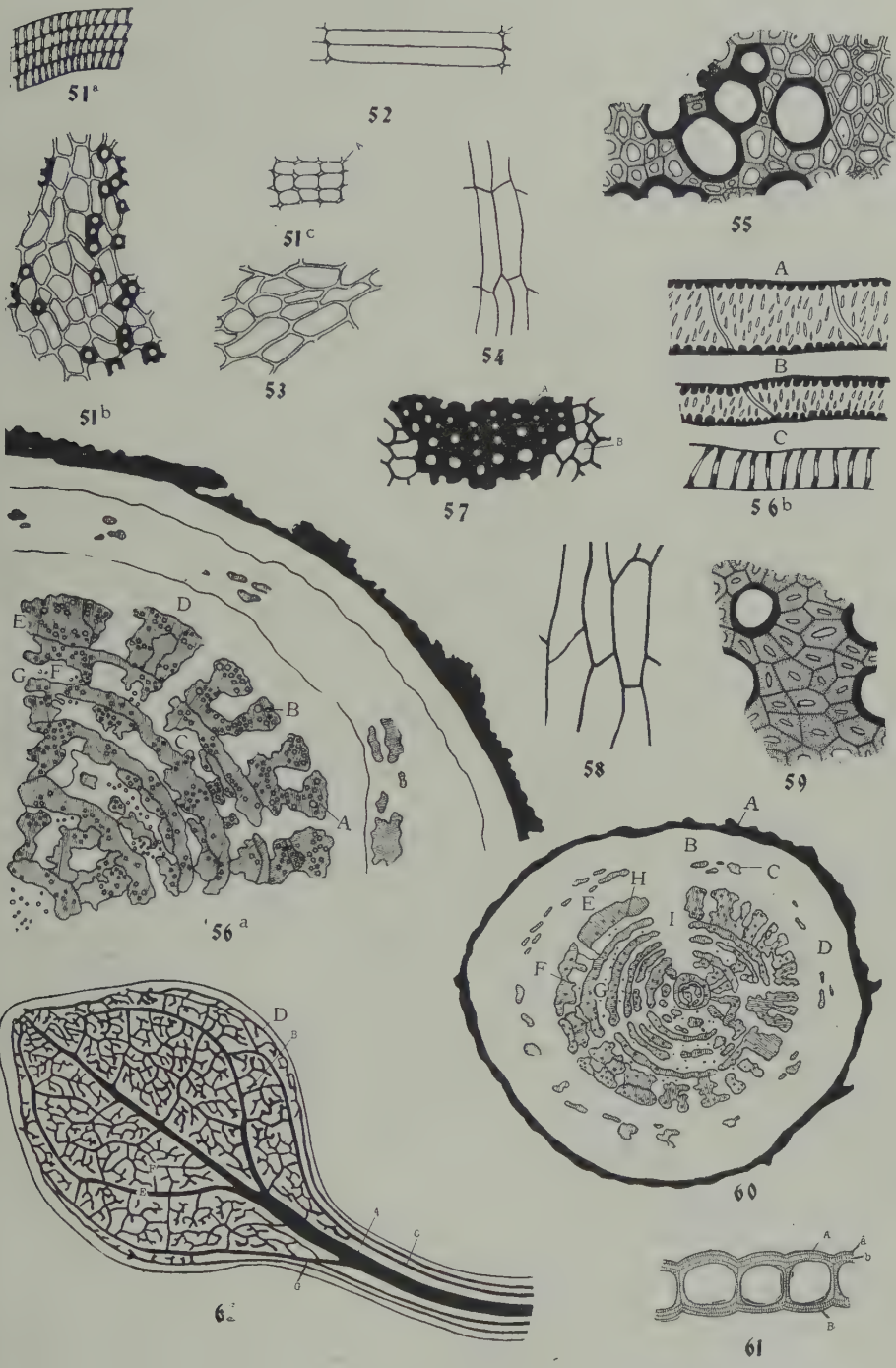
FIG. 58. Wood parenchyma cells, as seen in longitudinal section. × 650.

FIG. 59. Wood fibers and tracheal tubes found in the layer of xylem (fig. 56*a*, *G*). × 650.

FIG. 60. Diagrammatic drawing of the cross section of the root, showing: *A*, cork; *B*, collenchyma; *C*, stone cells; *D*, thin-walled parenchyma; *E*, phloëm; *F*, wood fibers; *G*, wood parenchyma; *H*, tracheal elements; *I*, medullary ray. × 65.

FIG. 61. Cutinized epidermis of leaf: *A*, outer tangential wall; *a*, cutinized portion; *b*, cellulose portion; *B*, inner tangential wall. × 650.

FIG. 62. A bleached leaf, showing the method of venation: *A*, central vein; *B*, lateral branches sent off from the midrib near the center; *C*, two prominent longitudinal veins found on either side of the midrib; *D*, *E*, *F*, terminations of veins; *G*, a large lateral vein sent out from below the center of the midrib. × 27.



The University of Chicago Library

PLATE XLV.

Lesquerella spathulata.

FIG. 63. Small portion of midrib of leaf, as seen in longitudinal section: *A*, spiral tracheary tracheid; *B*, undivided mother cell of the sieve tubes. × 650.

FIG. 64. Palisade cells, surface view. × 650.

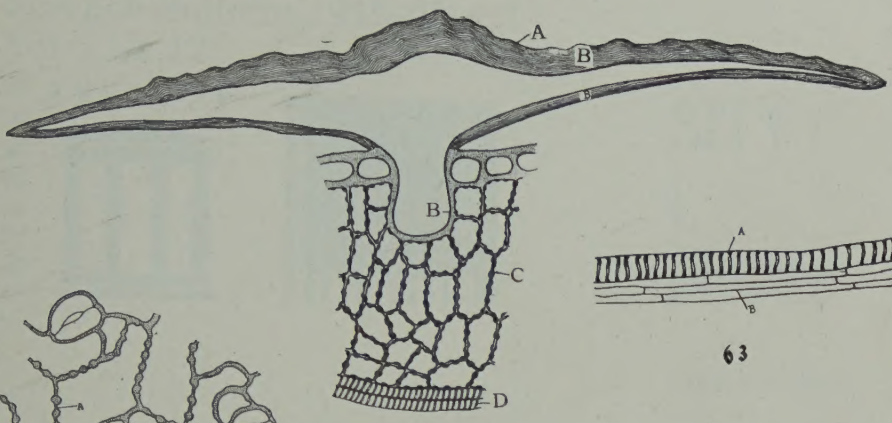
FIG. 65. Trichomes, as seen in surface view of the leaf. × 115.

FIG. 66. Trichome, as seen in leaf, cross section: *A*, cutinized portion of wall of trichome; *B*, cellulose portion of wall of trichome; *C*, mesophyll cells; *D*, tracheids. × 250.

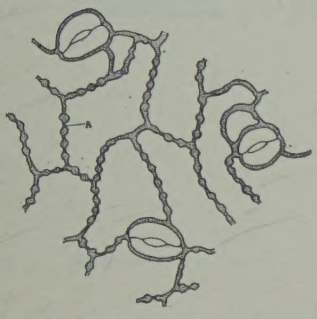
FIG. 67. Stomata, as seen in surface view. × 650.

FIG. 68. Stoma, as seen in cross section. × 650.

FIG. 69. Leaf, as seen in cross section: *A*, upper epidermis; *B*, lower epidermis; *C*, palisade tissue; *D*, vascular bundle. × 250.



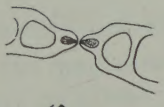
63



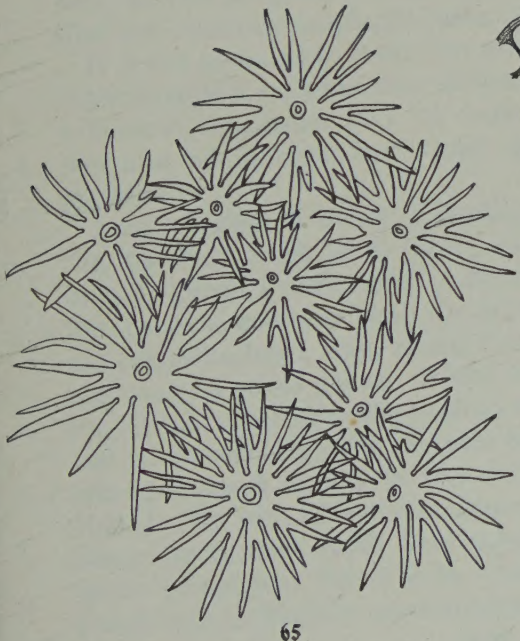
67

66

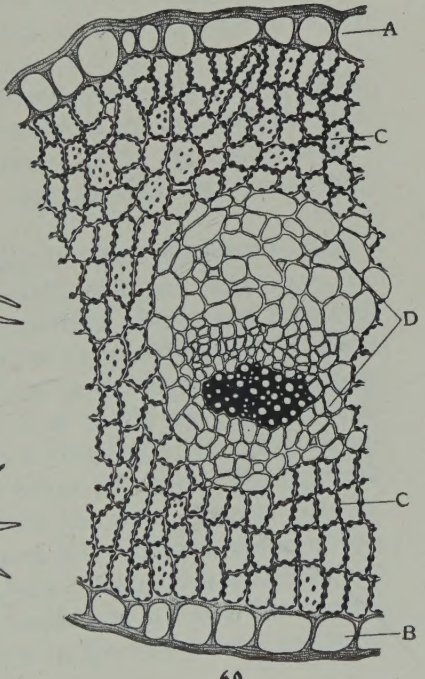
64



68



65



69

The University of Chicago Library

nests and thus nearer the necrotic areas than the indirectly dividing cells.

7. The indirectly dividing cells lie nearer the periphery of the nest than the directly dividing cells.

8. From these observations it may therefore reasonably be concluded that amitosis represents the final effort of the cell at reproduction, and that shortly after its occurrence degeneration ensues.

9. Amitosis, mitosis and disintegration comprise the cell changes in the alveoli.

10. Cells in direct and indirect division are larger than the resting cells.

11. In one stage of degeneration of the cells the chromatin becomes diffused through the karyoplasm and so swells that it fills the nucleus as a deeply staining, homogeneous mass. In another process of degeneration the chromatin loses its staining power and the cell becomes clear.

12. There is a shrinkage of the nuclear bulk in degeneration.

13. A border of chromatic cells lies between the vigorous cells and the cell debris of the necrotic area and marks the limit of degeneration; such cells are themselves degeneration results.

BIBLIOGRAPHY.

C. M. CHILD. Studies on the Relation Between Amitosis and Mitosis. Biological Bulletin, vol. XII, No. 2, January, 1907.

J. GEORGE ADAMI. General Pathology.

J. E. S. MOORE and C. E. WALKER. First Report on the Cytological Investigation of Cancer, 1906.

ALFRED STENGEL. General Pathology.

J. T. PATTERSON. Amitosis in the Pigeon's Egg. Anatomischer Anzeiger, Bd. 32, 1908.